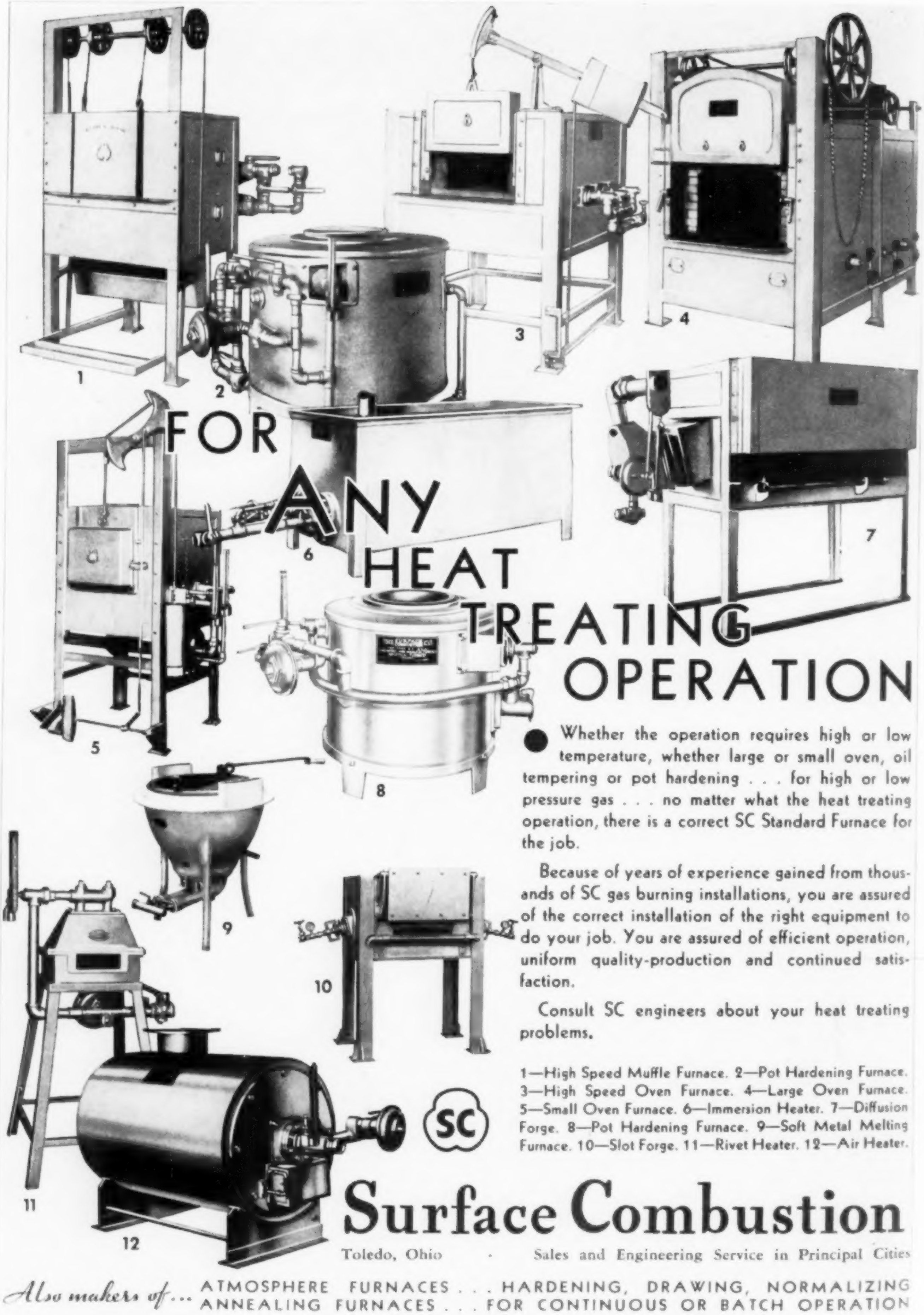
METAL

OVEMBER 1933

PROGRESS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METAL PROGRESS

Vol. 24 *November, 1933* *No. 5*

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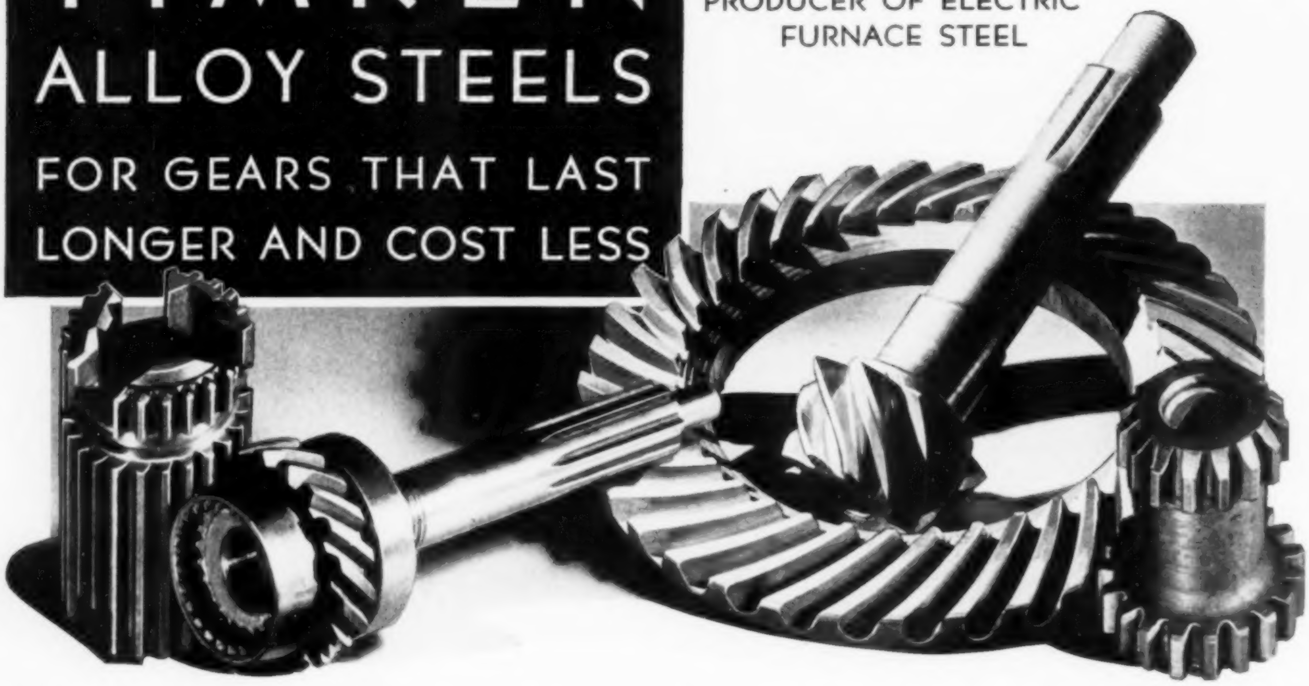

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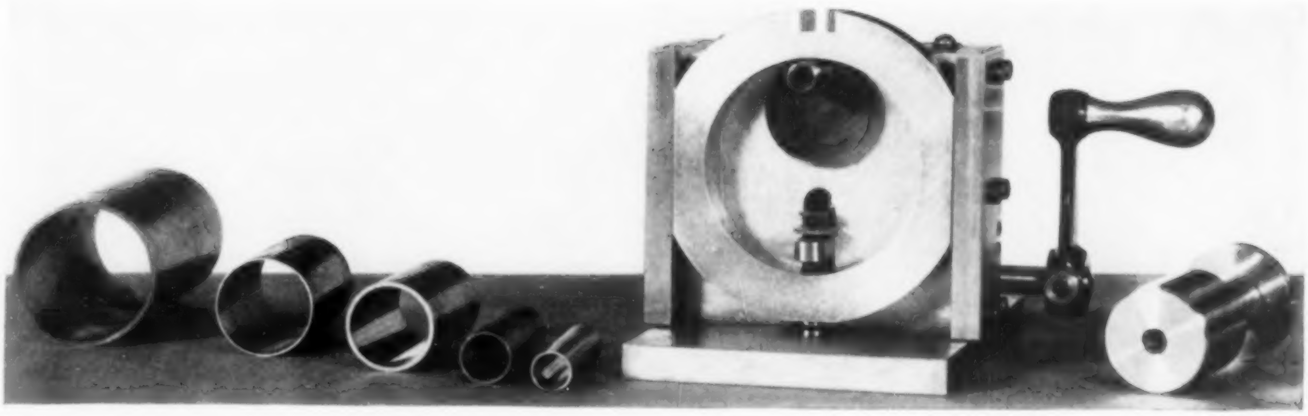
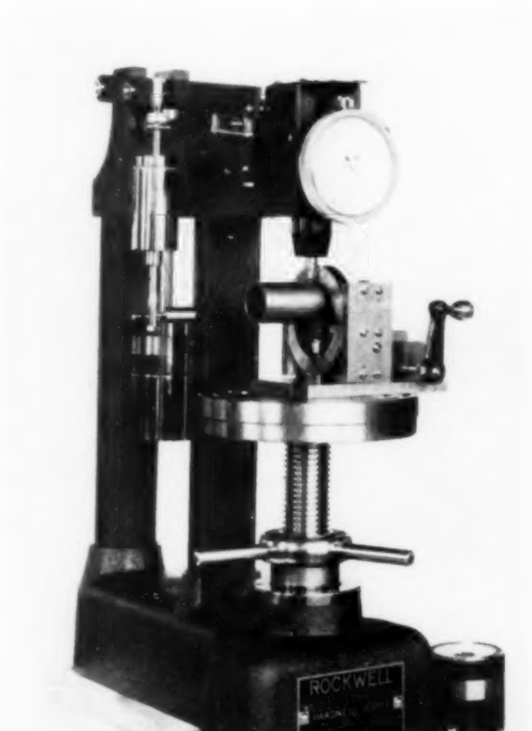


Testing Thin-wall Tubing on the "ROCKWELL"



It has been customary to make "Rockwell" hardness tests on tubing just as on solid round bars, when the wall of the tube is sufficient to prevent permanent set under testing load. Many tubes have walls too thin for that method. Pieces have then generally been cut from the tube and have been tested, convex side resting on the flat anvil or concave side resting on a mandril-like support.

Often, however, it is desired to test a thin-wall tube near its ends, but without cutting a piece out. This can be readily done on the "Rockwell" with the fixture illustrated above and which we have built for several tube companies. It is a clamp that gives proper anvil support and covers a great range of sizes with only two mandril-like members.

When the tubing is long the major length is supported by some suitable table or rest devised by the user to meet actual conditions.

Illustration at left shows anvil clamp for tubing on a "Rockwell".

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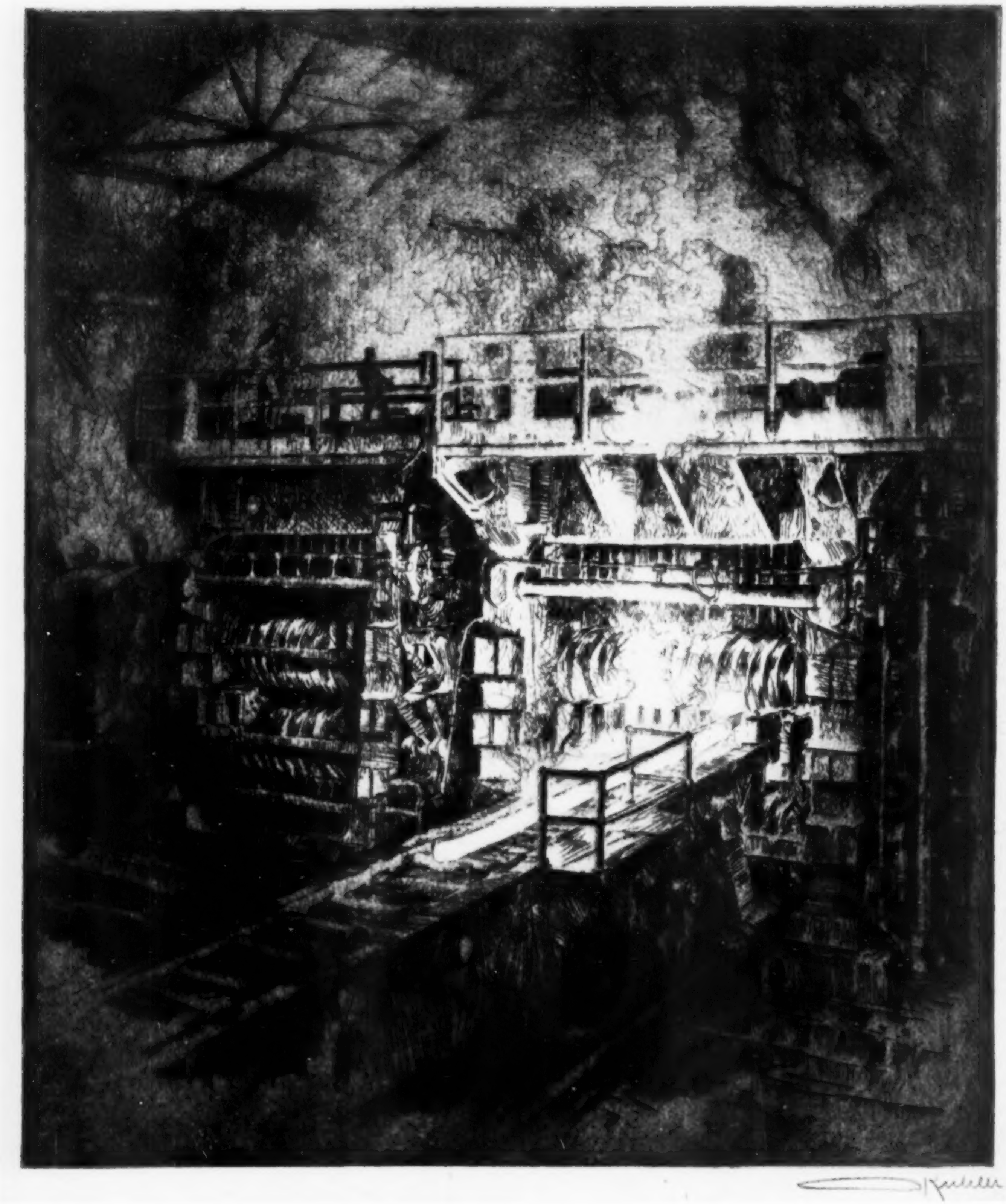


Rolling Billets at Timken

Etching by Otto Kuhler

Flakes are internal cracks caused by stresses set up when the forging passes through a depressed critical range. The remedy is a slow and controlled cooling rate. Never let the piece go below 700°F. until grain is refined.

Prevention of Flakes In Alloy Steels

The oft-recurring problem of "diseases" met in fine steels is not unlike that which the physician meets in combating ailments in the human body. Each generation there comes an epidemic of troubles which lessen as the individual citizen becomes more thoroughly appreciative of the root causes.

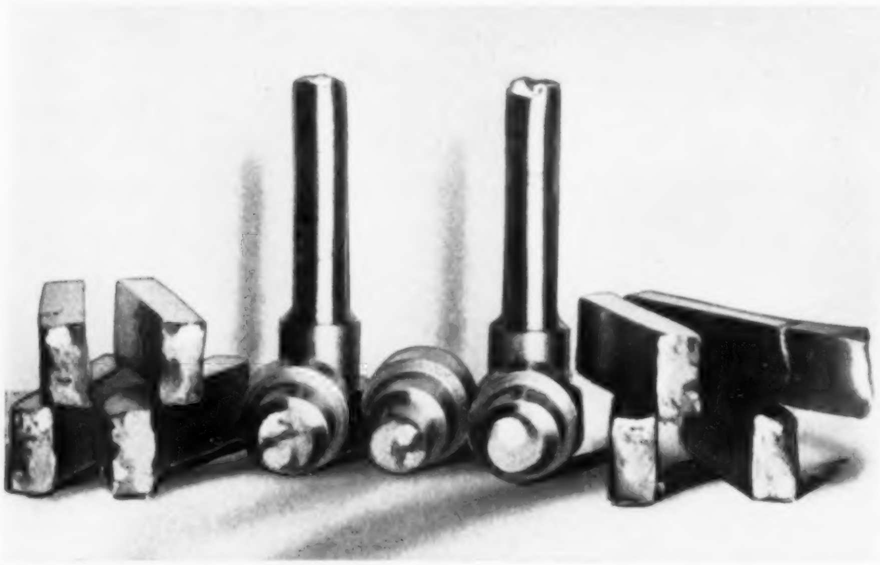
To illustrate the point, we may cite a few metallurgical examples that are as old as machinery: (1) Failures resulting from the concentration of stresses at sharp corners and angles. (2) Failures which result from tool marks left on highly stressed surfaces, such as axle journals, or failures due to the chatter marks from rough cutting too near to finish size. (3) Unsuspected grinding cracks, due to heavy grinding or grinding with a dirty, loaded wheel. (4) Longitudinal cracking of journals which, while carrying a direct load and running at relatively high peripheral speeds, are highly stressed on the surface due to repeated heavy braking action.

So-called flakes as a cause of failure are more recent. They appeared when alloy steels were adopted by the engineering industry. Although this disease was known to some of us 25 years ago, the sudden expansion and application of alloy steels during the War brought with it a world-wide epidemic of this trouble. Possibly the situation was most acute in the United States, owing to the large number of plants which were suddenly called upon to make, for the first time, alloy steel forging billets and alloy steel forgings. It may fairly be said that the problem was not whipped at that time, as far as American forge shops were concerned, for even at the end of the War rejections of gun tubes were large. From 1918 to 1920 the editor of Metal Progress was responsible for the publication in *Chemical and Metallurgical Engineering* of a number of articles from different observers on the causes and prevention.

By H. H. Ashdown
Metallurgist, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

As a result of several years' previous study of this subject, the writer in 1916 presented a paper to the Sheffield Metallurgical Society, England, indicating the cause of this disease and the stage of manufacture at which flakes developed. The views of the fractured test pieces and plate reproduced on page 14 and 15 were submitted on that occasion. At that early period the suspected cause was a volume change at a comparatively low falling temperature when the metal was in a relatively weak structural condition. One reason for this conclusion was that certain types of large armor-piercing projectiles developed flaky fractures when the forgings had been allowed to cool normally instead of very slowly.

Since that time a number of papers and



Standard Tension and Bend Test Bars Which Exhibit Flakes or Cracks Existing in the Original Metal

technical articles have been published, including one by the writer which appeared in *Iron Age*, May 8, 1930. A correlation of the literature on this subject appeared in *Metals and Alloys* in April by Sauerwald, Gross, and Neuendorff, who also confirm by their researches the above-stated cause of this disease.

The necessary precautions to prevent it have been discovered and in many instances are now being applied. The writer has, however, quite recently seen several instances of this trouble. It therefore may be assumed that these are not isolated cases and as these defects may at any time lead to most serious consequences, a retrospective review is deserving of the publicity it is again receiving.

Volume Changes During Cooling

Many of the common alloy steels have a low critical range when cooling from the high forging heat. It is well into a black heat, and in this state the material has become very rigid, with a very small capacity for deformation. Changes from austenite (gamma iron) to pearlite (alpha iron) involve an expansion in volume, which develops high tension stresses and may result in many small internal fractures. It will be appreciated that large forgings usually are of a comparatively coarse crystalline structure, which again offers planes of weakness and a more easy path for fracture due to these highly developed stresses.

If a forging or rolled bar known to contain these defects is fractured in the as-forged condition, these defects are not detectable because, like the cracks themselves, the whole fracture has taken place through the coarse crystalline boundaries. Furthermore, the facets of these small cracks are not discolored, since they have been sealed within the material and oxygen excluded. If a portion of this forging is now taken and refined by quenching and drawing and then fractured, the cracks which have occurred in the first cooling from the forged condition will still present the shiny, coarse, crystalline fracture and be highly reflective, while the major portion of the steel will have assumed a much smaller grain size presenting a comparatively dull background.

As these defects often do not develop at the extreme ends of the forgings, a reasonable crop end must be removed before polishing and etching. They then appear as black lines.

Evidence that these defects take place immediately after forging is that with few exceptions these small fractured areas are almost entirely circular and reasonably flat. Had they existed in the ingot or occurred during the forging process they must have been elongated and would have an orientation favoring the direction of maximum work. Again, we may take a large forged bar and cut it in half while it is still at forging temperature, and allow one half to cool on the floor. That half will be found full of these defects. By taking certain precautions with the other half, it will be found to be entirely free from them.

Some observers, notably Giolitti, believe that flakes are induced by or at least associated with non-metallic inclusions in the steel. This

must be a secondary cause, for in our experience the steels most susceptible are the cleanest and most carefully made, and those more immune are the dirty steels which on that account show very unsatisfactory transverse physical properties. It is possible that the "woody" fibrous fracture due to distributed slag has been confused with the flaky fractures now under discussion.

In the article contributed in 1930 to *Iron Age*, we gave an account of splitting an ingot down its longitudinal axis, forging one half into a round bar and allowing it to cool in the atmosphere. On examination this exposed numerous flake ruptures all radiating from the central axis of the bar, not from the region which was originally the central axis of the ingot. This indicated that the primary structure of the ingot or segregates had little relation to this trouble.

In all the large masses handled by us and known to be sound after the forgings had been carefully grain refined, we never met with any single instance where defects of any nature occurred due to subsequent treatment operations, even after drastic quenching. It should, however, be noted that these massive forgings were never allowed to go cold until they had been grain refined, nor cooled stone cold following quenching until after the final tempering heat. (When quenching large caliber ordnance forgings, the muzzle end, while still warm, was gradually withdrawn from the quenching medium and the heavier mass tapering to the breech was cooled to the same uniform temperature. In this condition the warm forging was transferred to a mildly heated furnace, automatically revolved, and the temperature gradually raised to the desired heat.)

It becomes evident, therefore, that in combating flakes we are more concerned with the procedure immediately following the forging or rolling. We must also assume, and rightly so, that *all* alloy steel forgings of reasonable weight and above 3 in. cross-section are subject to this disease. Actual examples in tool steel, plain carbon steel and 5% chromium steel will be given later in this article.

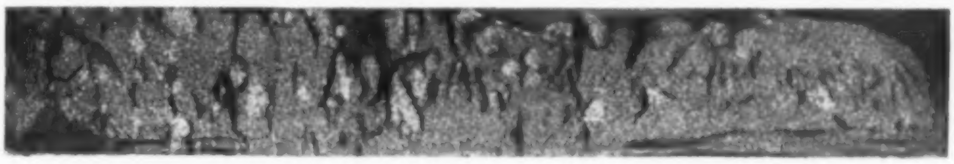
Gun Forgings

One commentator infers that flakes are peculiar to gun forgings of alloy steel. That is not true, as any hollow forging with a wall thickness exceeding 3 in. or a solid forging of greater cross-section than 3 in. made from the same type of steel is subject to this trouble. But there is good reason why gun forgings should receive particular mention.

One large ordnance company lost at least four 15-in. guns from this very cause. For each forging an ingot weighing approximately 180,000 lb. was required, yet suspicion was only raised when a great number of hairline cracks appeared on the polished interior of the bore, all ready for the rifling operation.

This serious loss called for a thorough investigation. The material in all four guns was of a particularly clean character as shown by microscopical and macroscopical investigation and as proved by the following average transverse tests, taken tangent to the bore at each end of each forging (which again was confirmed by transverse tests taken from the mid-length of the scrapped forgings).

Yield strength	104,600 lb. per sq.in.
Tensile strength	127,000 lb. per sq.in.
Elongation in 2 in.	16.2%
Reduction of area	32.0%
Bend	180°
Izod impact	36.5 ft. lb.



A Fractured Plate, About 2 In. Thick, Cut From Center of 10-In. Slab Full of Flakes

As a preliminary investigation, it was decided to cut one forging in half. From one end a complete ring about 2 in. thick was removed; one transverse face was polished, and on etching numerous hairlines were observed, varying from 1/4 in. to 3/4 in. long, traversing the thickness of the wall. This ring was then fractured across its central axis and a large number of the characteristic circular flakes were exposed corresponding with the etched lines. Although these cracks extended to the bore, it will be appreciated that on a piece of this character about 3/4 in. of material would have been removed by machining, so that it is doubtful if these defects extended to the original forged surface.

From what has already been said, it will be appreciated that a test piece cut from a suspected piece will or will not show flaky fractures, depending on its location. Since the defects are comparatively deep seated, the best method of inspection is to examine the axial bore of a forging with a periscope. For such purpose the internal finish must be smooth enough so the hairline cracks may be readily distinguished from polishing scratches. A useful method of emphasizing the cracks is to etch the bore lightly before examination to give them the appearance shown above, repolishing the surface when it has been accepted.

It had long been recognized that work on alloy steels, down to a temperature of around 1500° F., causes internal stresses in the material. This is the range of cold work, rather than hot work. It was decided that no future forgings should be worked below a temperature of 1600° F. Added resistance to flow of the steel below this degree is readily indicated at the forging press by the increasing pressure necessary to effect displacement, or by the solidity of the blow from the hammer.

Recommended Practice

Forgings completed in one heat may be taken directly to a preheated annealing furnace and equalized at 1600° F., then allowed to cool slowly down to 500° F. in the sealed furnace, reheated to 1600 to 1650° F. to refine the grain, and again allowed to cool slowly down to room temperature. Long forgings requiring two or

more heats, and which had been worked up to the stage preparatory for turning round the unforged end into the furnace and the finished end out, were taken to a special annealing furnace. In this furnace, which was taper heated, the finished end was heat treated, grain refined as a finished forging, and then allowed to cool normally (all danger of flakes having thus been removed), while the opposite end was raised to and maintained at 1100 to 1200° F., preliminary to inserting into the forge furnace.

Although this is the safest procedure, it is somewhat costly. A less certain method (although in most cases it has proved quite effective) is to bury completely in sand or dry ashes those forgings which are finished in one heat, thus allowing them to cool down very slowly and uniformly through the critical range. The heat in the forging is sufficient to equalize them, providing, as already stated, forging has been completed at a good red heat.

Forgings of considerable length require several heats and must be turned end about in the furnace; the hot end outside of the furnace must be suitably protected to insure slow cool-

lakes in a 6½-In. Round Bar, Cut Some Distance From e End. Polished and Etched With 5% Nitric Acid in Alhol. At bottom of page is axle, broken for study after milar forgings had developed suspicious internal checks

ing. Hollow forgings may be given a feed of coal or coke, the open end bricked and clayed up, and the whole buried in a mound of sand or ashes. When it is necessary to turn the forging over to equalize the heat, great care must be taken not to uncover the buried portion, as it may be at this very period that it will be passing through the dangerous temperature zone and all precautions so far taken would then have been of little service.

Where forgings are known to contain flakes, they need not be scrapped, as these defects have perfectly clean, unoxidized faces. At a forging heat they will weld together perfectly. Macroscopic and microscopic examination of these reworked forgings shows complete homogeneity; transverse tests indicate normal physical properties. Solid forgings may, therefore, if flaky, be reforged to reduced diameters and hollow forgings expanded on the mandrel. It is, of course, understood that these newly made pieces will receive subsequently the careful heat treatment advised to prevent the reappearance of these defects.

Large turbine forgings and generator rotor forgings (whether one piece or of the built-up type) are fast reaching their limiting dimensions when made of carbon or mild alloy steels. Designers are alive to the risks confronting any such forging, with marked changes in cross-section, when subjected to any form of liquid quenching.

To meet the demand for increased ratings, the only present alternative appears to be to depend upon air hardening alloy steels of the nickel-chromium-molybdenum types. Here both the steel manufacturer and design engineer are confronted with the risk of numerous incipient cracks due to the widely differing rates of cooling of the various portions having marked changes in cross-section. Such large forgings will require to be handled with all the care already indicated for massive alloy steels. The same degree of finish in the bore and careful interior inspection are absolutely imperative.

Flakes in Other Steels

It has been stated that alloy tool steels are not subject to these defects. This is incorrect, as we have seen instances of it. If tool steels in heavy cross-section are carelessly handled, they are not at all immune. On one instance, the hammer broke down during the forging of a large tool steel billet, locking it between the blocks and holding it thus until it was practically cold. Subsequent examination showed the material to be badly flaked.

The main reason why this defect is not more often seen in alloy tool steels is that they are carefully nursed at every stage of manufacture, are carefully cooled at the billet stage (where the surface is inspected and chipped), and usually are not allowed to get cold again until they assume the finished form.

We have also seen one serious example of this evil in straight carbon steel of about 0.40% carbon. It resulted from an effort to meet a rush order for two large crankshafts, both of which fortunately were scrapped before leaving the manufacturer's plant. One broke in twisting the throws, presenting *(Continued on p. 62)*

Razor blades in production are tested by cutting a hair, by feeling the edge with a moist finger, or by viewing a stack of edges under a spot light. Mr. Peters suggests that shavability requires an edge neither too rough nor too smooth, and measures this microscopic roughness by corona discharge

Measuring Sharpness of Razor Blade Edges

UNLIKE electricity, which can be measured but not defined, "sharpness" is easily understood in theory, although in practice it has persistently eluded all known methods of quantitative determination. Individual opinion is the principal determining factor.

Almost all industrial cutting tools operate as a wedge rather than an edge, prying rather than cutting the chip off. In such tools, the angle and the frictional coefficient of the upper bevel are far more important criteria of cutting efficiency than the edge itself. Safety razor blades are unique in a cutting action almost entirely devoid of wedge effect. A study of razor blades unfortunately introduces a new criterion, for shaving efficiency is measured in terms of personal comfort rather than force, and personal comfort is greatly affected by edges having the slightest tendency to drag or pull, even though such edges might still pass with flying colors any sharpness test which is not expressed in terms of pain.

A correlation of elementary data on edges, already at hand, indicated that it is neither the polish nor the angle of the bevel nor the profile of the cutting edge, but the minute radius of curvature of the edge proper (just where the two bevels join together) which is the ultimate criterion of cutting efficiency and shaving comfort. The ideal edge may be visualized as a smooth, uniform and extremely narrow half cylinder having a radius R. In practice, the edge is revealed under a microscope as a series of more or less jagged peaks, the magnitude of which seems to be dependent on the microstructure of the steel and on the sharpening process. In theory, these peaks should be aligned at the intersection of planes X and Y of the first sketch on page 20. In practice, this could never be claimed for a fact.

It would appear that any deviation of the cutting edge line from its optimum location at the intersection of planes X and Y would not be objectionable of itself, were it not for the attendant variation in both sharpness and cutting characteristics of the edge along such deviating sections. When, for instance, a grain of steel happens to be torn away by use, producing a small valley or nick, the "dullness" is not due to the impaired profile so much as it is attributable to the fact that, in cross-section, it has a greater radius of curvature. This means that the edge, at that particular point, has a tendency to shear rather than cut. On the other hand, should the edge protrude beyond its normal position in an excessively fine peak ("wire" or "burr"), it might cut better than the rest of the edge but could not stand up and, having collapsed at the base, would be likely to turn into relatively large radius. The problem is to produce an edge that is not only sharp and uniform but durable as well; an edge neither

By Peter N. Peters
New York City

too sharp nor dull but just right — in between.

Indications are strong that the shift of the entire edge line in the plane Y is of no moment if other dimensions remain the same. The performance of such a blade in a holder, however, may be totally different, because of a changed angle of attack, and other factors introduced in combination with the holder. Should any such deviations occur only in some sections along the edge, the effect would be distinctly detrimental — yet such blades, by virtue of their "hacksaw effect," have been often found to perform very well in several accepted sharpness tests except the actual shave. An individual peak inclined toward the face may scratch the skin, whereas a deflection away from the face would bend the hair follicle and cut it at an acute angle, if at all, and produce the razor "pull" which is so objectionable.

Incidentally, the advantages of the freely advocated diagonal, or "barber's" stroke, are due to the fact that the hair is severed by a series of comparatively shallow but successive incisions caused by a procession of peaks. In other words, the diagonal stroke is beneficial primarily because the edge line is never smooth and, even at best, the theoretical half-cylinder may be visualized as an uneven and more or less meandering ridge.

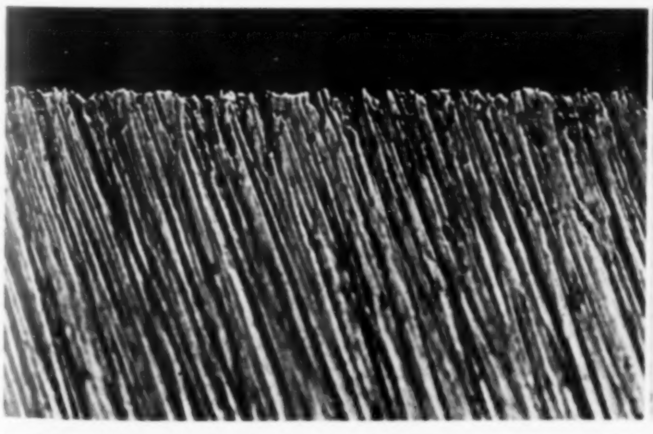
The individual peaks or mounds along this ridge must be of proper dimensions. When too large, they neither bite into nor cut the hair; for this reason relatively coarse grained edges tend to be a little dull. Conversely, when the grains are small enough to bite at once without dragging the hair follicle in search of a sharper or, rather, rougher spot — and yet not too small to collapse during the very first cut — a perfect shave should be the logical result. The third condition, when the grains are either too small or too soft to penetrate, renders such edges just as unfit for use as the ones which are too dull. The grains mentioned above need not be steel but may be due to oxides such as rust. (Naturally, as was pointed out before, none of these conclusions apply to industrial tools which cut as a wedge rather than as an edge.)

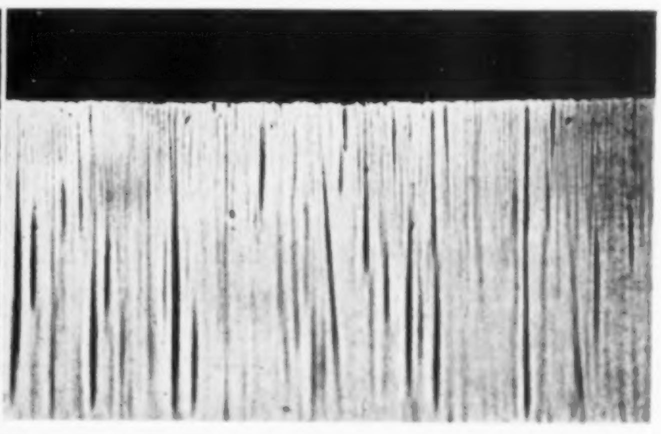
The theory that, within certain close and definite limits, sharpness is synonymous with roughness, readily explains why none of the many sharpness tests now in existence can be successfully correlated with actual shaving experiences.

To begin with standard factory inspection: This is practiced today by viewing stacks of 200 to 500 blades at a time at an angle of about 45° to a beam of light. The inspector notes the variations in intensity of the reflection from the edge due to the slightly flattened portions at nicks, wire, and dullish or "gray" sections. Within the last few years, several attempts have been made to use a photocell for measuring and recording these variations in light intensity, with some experimenters reporting very encouraging results. (See R. W. Woodward, *Iron Age*, June 22.)

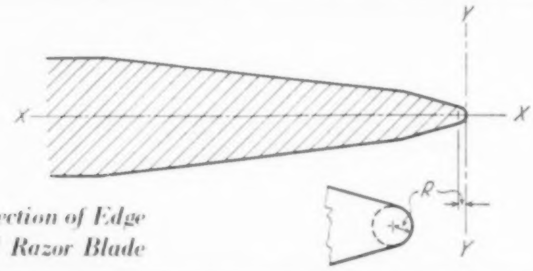
Crude as it is, such factory inspection still seems to be the best, most rapid, and reliable

Razor Blade Edges at 200 Diameters. Honed edge at left, polished edge at right. Courtesy Electrical Testing Laboratories





method of production control available at this time. Unfortunately, it is limited to the detection of irregularities well in excess of the degree fatal to comfortable shaving. No amount of naked eye examination or scrutiny under a microscope reveals the difference in shavability of two cutting edges both of which are sharp,



Cross-Section of Edge of Ideal Razor Blade

but one somewhat sharper than the other. Yet this particular problem of grading *sharp* edges is of utmost importance to the industry in setting and adjusting the sharpening machines. (Such adjustments are still being made by the trial and error method, dependent entirely on the personal opinion of the operator.)

Examination under a microscope may reveal defects which cannot be observed by the naked eye. Adequate magnification, however, presupposes accurate focusing. Accurate focusing means that the edge may be viewed only in one plane, yet the edge is essentially a three-dimensional affair. It is, perhaps, this three-dimensional characteristic of the cutting edge which tends to detract from the value of a microscopical examination. The profile of the edge, however highly magnified, is not necessarily a criterion of its cross-section normal to the plane in view.

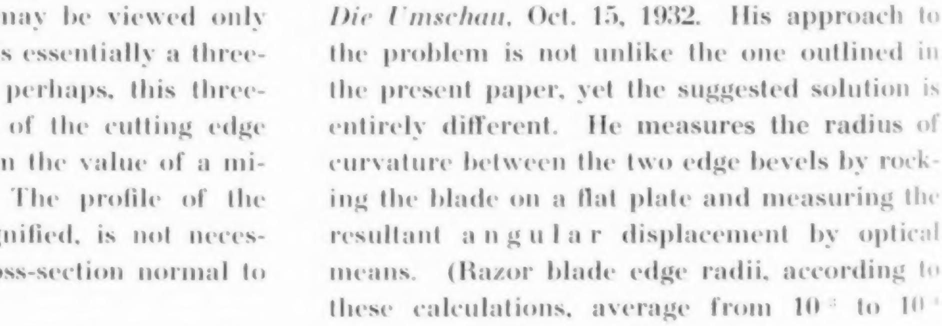
Hence, visual tests have only a negative value — an edge observed to have a defect could be assumed to be defective, but the reverse does not necessarily hold true.

Among the several paper-cutting tests which came in for a great deal of comment outside the safety razor industry but evoked very little interest within, the better known is done in a device described by Honda in METAL PROGRESS, March, 1931, and in more recent equipment proposed by Palmer in *Consumers' Research Bulletin* for April. The hacksaw effect of a blade edge penetrating a stack of paper strips seems to be an important factor in the Honda procedure, while the angle and the polish of the bevel may often tend to obliterate the true significance of the readings taken on the Palmer apparatus.

An effort to eliminate the wedge effect led to the development of the thread cutting machines of various designs described by Woodward. In these the blade is made to sever a taut thread; the force is used as a criterion of sharpness at that particular point. The conditions of the test are a somewhat better approximation of those which obtain in the actual shave — assuming that the thread remains uniform.

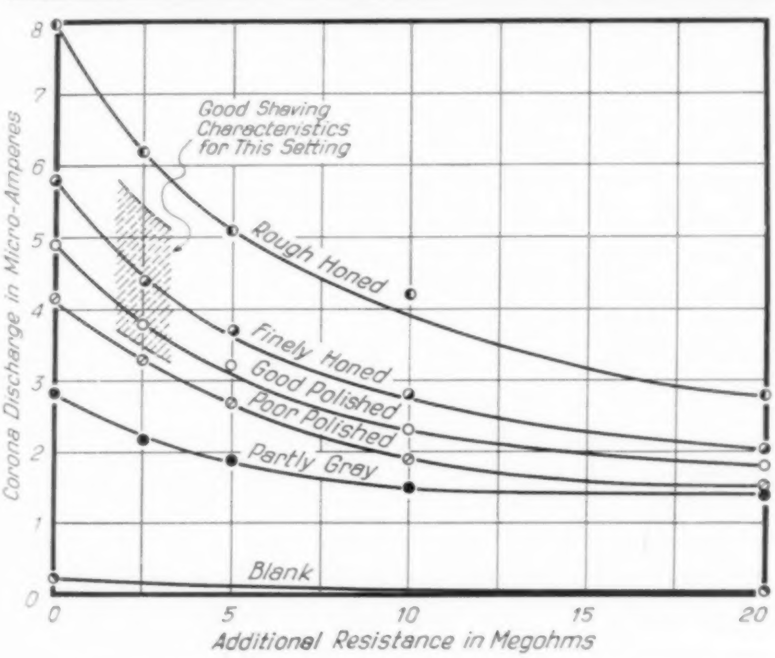
The latest method and apparatus for quantitative determination of sharpness have been announced in Germany by G. Schmerwitz in *Die Umschau*, Oct. 15, 1932. His approach to the problem is not unlike the one outlined in the present paper, yet the suggested solution is entirely different. He measures the radius of curvature between the two edge bevels by rocking the blade on a flat plate and measuring the resultant angular displacement by optical means. (Razor blade edge radii, according to these calculations, average from 10^{-3} to 10^{-4} mm., or 0.00005 to 0.000005 in.)

Wiring Diagram of Installation for Measuring Corona Discharge From Sharp Blades. Motor-generator set produces waves of desired characteristics, which are passed through a voltage regulator, step-up transformer, and tube rectifier. Leakage across air gap between blade and bar is measured by galvanometer, or estimated visually by skilled inspector



Foremen and superintendents at blade manufacturing plants are inclined to take all above tests, with the exception of the accepted factory inspection, with more than a grain of salt. They prefer to use their own methods, which, assuming intelligent interpretation, still seem to be the most reliable of all. The "hair test" is their one standby; the "finger touch" is the other.

Unfortunately, the hair test lends itself altogether too readily both to misuse and to abuse, since few razor blade edges are incapable



Effect of Increased Resistance in Circuit on Sensitivity of Apparatus. Equipment may actuate magnetic selectors to remove any blade discharging less than $3\frac{1}{2}$ micro-amperes (a poor polished edge) or more than $5\frac{1}{2}$ (an edge quite rough)

of passing it if the demonstrator is at all adept. The closer the cut is made to the point of support, the easier the follicle is severed by the blade before it has a chance to bend. Another favorite trick is to drag the hair along the edge, as if the latter were a string bow. Sooner or later, there will be encountered a section rough enough to bite into the hair and just at that time, the follicle is given a barely perceptible jerk and is cut in two. Follicles cut during such "testing" reveal angles so acute that they look as if they were split!

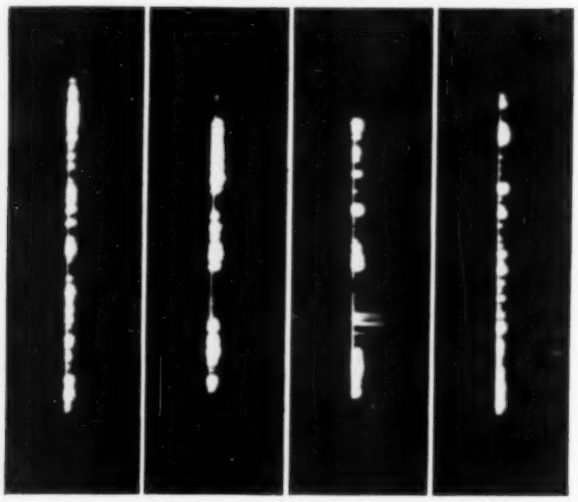
The second test — the finger touch — is more reliable. A finger, preferably moistened, is carefully brought in contact with the blade edge and then gently dragged along it. The sense of touch seems to offer an excellent index of edge roughness, but this test is limited by its subjective characteristics.

Static Discharges

Early appreciation of the fact that it was virtually impossible to measure directly a three-dimensional quantity as small as the edge curvature prompted the writer to investigate an indirect measurement — that is, some other function quantitatively related to these radii. Electrical surface density was selected as such a readily measurable function, and the "corona discharge edge testing method" was developed as the result.

This is based on the well-known fact that, when an insulated electrical conductor of irregular outline is charged to a certain potential, the charge is distributed so that its density at any given point varies inversely with the radius of curvature at that particular point. When applying this principle to the testing of cutting edges, this surface density is stepped up high enough to cause a discharge to take place into the surrounding medium and its intensity and rate are accepted as criteria of cutting edge characteristics — that is, its roughness — at this particular section. In practice, the discharge is usually made to take place across an air gap separating the edge from a smoothly polished and plated bar of larger diameter.

In its simplest modification the testing circuit may comprise a secondary of a step-up transformer in series with a blade and an ordinary micro-ammeter. A metal bar faces the blade edge across an air gap, and the self-rectification characteristic of the edge-to-bar discharge is sufficient to produce unidirectional current of several micro-amperes. The dis-



charge can be observed and photographed in the dark, although photographing is not recommended in view of the detrimental effect of ozone during the necessarily long exposures. A somewhat more elaborate installation is shown in the diagram on page 20, with some of its readings on the curves, page 21.

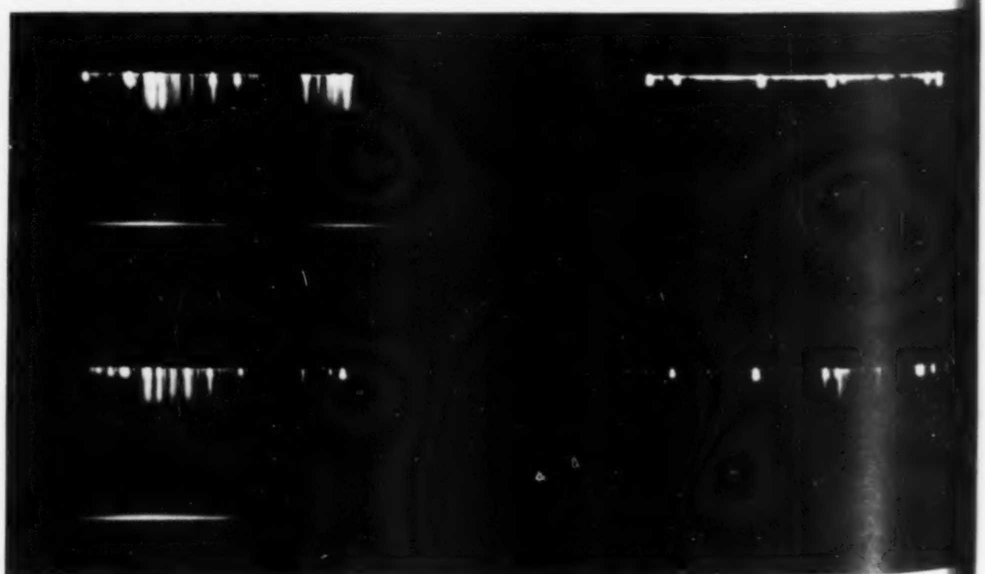
So much for a quantitative measure of micro-roughness. Durability of the edge is yet to be investigated. The corona discharge test is in full accord with the assumption that, as far as shaving is concerned, sharpness is synonymous with microscopical roughness, but only within certain close and definite limits. If no particular care is given to the edge beyond wiping dry or almost dry, the corona discharge seems to increase on the next day rather than right after the shave. This increase depends on the metallurgical characteristics of the steel.

If a new edge is simply left in the open, unprotected, where humidity may affect it, it seems to deteriorate very rapidly even without any use — which tends to bear out the hypothesis that life of the blade edge is shortened by chemical rather than by mechanical disintegration. The older the unprotected blade, the rougher the edge, and the greater the corona discharge.

Stropping action may also be construed as offering some corroborative evidence, for stropping is primarily intended to remove the chemical film along the edge, rather than to straighten out the imaginary teeth. Another significant fact is that an old-fashioned razor seems to shave better after a few days of rest; hence, the time-honored custom of having a separate razor for every day in the week. A plausible explanation is that stropping tends to become somewhat more effective when the chemical film — if there be such film — is given an opportunity to acquire some thickness, which seems to make it less tenacious than it would be if attacked in its incipient stage.

The usefulness of the corona test need not be limited to the razor and cutlery industry. Since it is substantially a method for determining the degree of roughness, visible or invisible, the development may prove to be of value to research in totally unrelated fields. Degree of polish, effect of lubricants and friction, and progress of corrosion are possible studies.

Views at Top of Page are Corona Discharges Along Four Blade Edges of Varying Uniformity. View alongside represents corona discharges along a new (left) and a used edge (right), taken at 9000 and 9500 volts. The difference between incipient and acquired roughness, in terms of luminous discharge, is readily apparent



Single operation presses may be standard, but progressive presses must be extra strong. Dies are made to resist unusual abrasion, even with a special lubricant and proper clearances maintained. Heavy pressures and double draw beads are required to prevent wrinkling the formed surfaces.

Stamping Automobile Parts of Stainless Sheet

OTHERS making stampings of the stainless steels (or as we have always referred to it — "rustless") or contemplating such fabrication may be interested in some notes on our experiences since 1930, when Ford's initial use for drawn objects began. That year's model had a rustless radiator shell, as well as lamps, hub caps, and some minor fittings.

In the press shop we used the same presses for making radiator shells as when they were made of ordinary steel. At the beginning of the line the large sheet (79x30x0.026 in.) was sheared into two sections; each was punched into an oval shape. These were passed through greasing rolls and then directly to the first deep drawing operation. Here the oval was drawn into a form 4½ in. deep, as shown on page 26, on a toggle press of about 250 tons capacity, using the same drawing speed as required for ordinary carbon steel sheets. An air attachment adjusted to 35 lb. per sq.in. pressure on the knock-out pad locked the blank to the drawing punch to prevent the metal from skidding.

Because of unusual pressure used on the draw rings to keep metal from wrinkling, it was found necessary to provide double draw beads on the long side so that this pressure could be reduced and still form good shells. Considerable experimenting was necessary to determine the length and position of the draw beads, as these elements were found to be rather critical.

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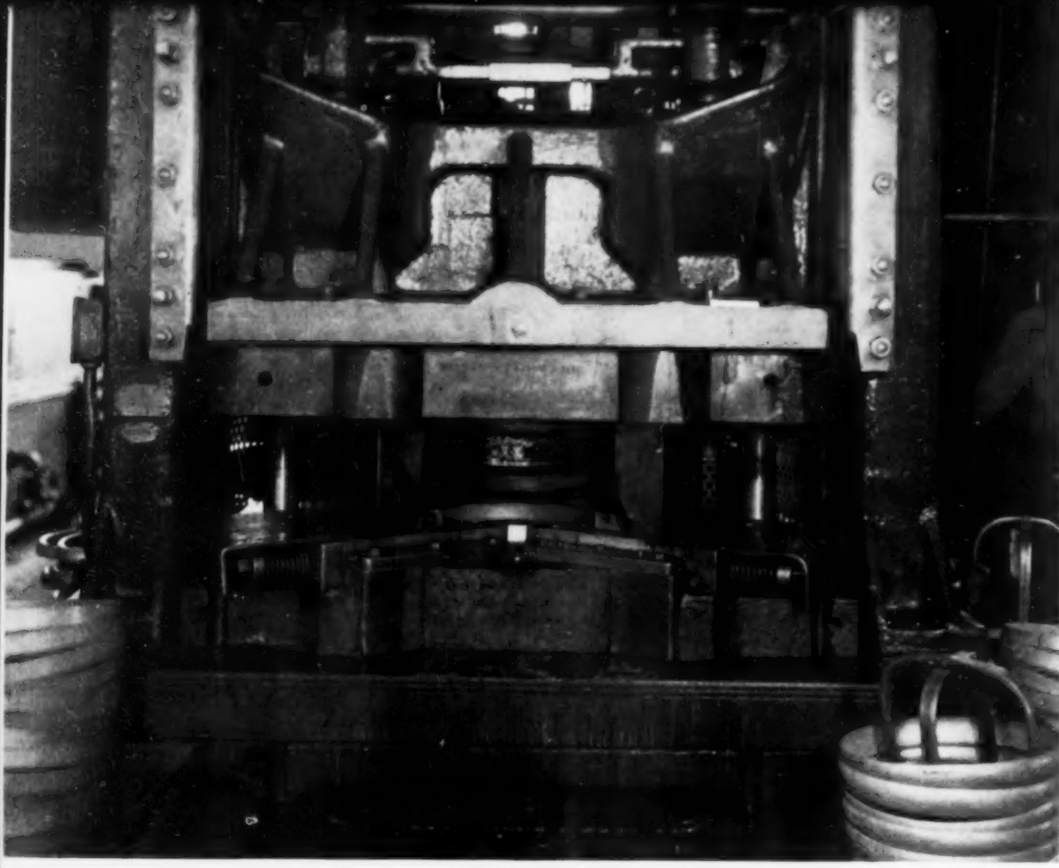
In the second operation the excess edge on the shell (due to additional draw beads) was trimmed off. The third press operation was a redraw, which straightened the sides and provided a general contour finish all around. An expanding die was the fourth and rectifying operation. Succeeding operations (such as punching holes, done in an expanding die) were performed individually in separate set-ups, making a total of 17 operations.

Before the shells left the press shop they were inspected and necessary repairs made by hand to remove rough spots which might cause difficulty in polishing.

Compared with the ordinary carbon steel sheet, rustless steel sheet is approximately 25% more ductile, but the ductility decreases faster during drawing operations, due to its work-hardening properties. Rustless steel sheet is relatively softer and yet is stiffer, due to its higher yield point, and demands a greater allowance in the die for the spring-back. It requires considerably more pressure to form, thus inducing severe abrasive action and inordinate wear on dies.

Accordingly, die design must be modified



At Right Is Press With Eight Stations Used for Head Lamp Shells. Round disks are fed from a magazine, and transported from station to station by suction cups. Dies include first and second draw, trim, third draw, and four finishing operations around the flange

Head Lamp Door Frames Start as Hoops Butt Welded From Strip. The partially shaped ring is given the barrel contour in this expander. Interior pressure is given to the hoop through a rubber disk

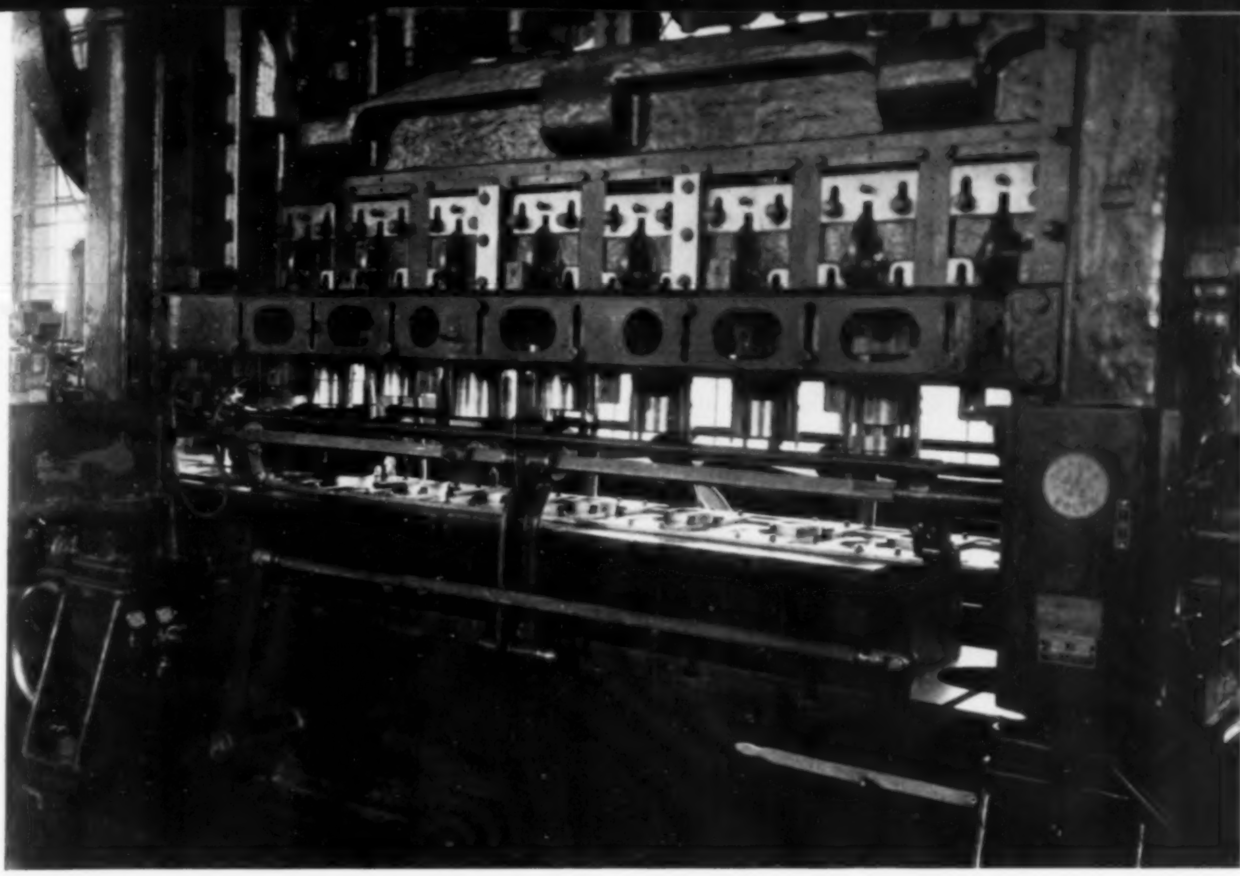
and special die steel is used, as will be explained later. Moreover, a special drawing solution for lubricating the sheet and dies is required. It was developed by the Ford Motor Co., and while empirical, has excellent properties. It is merely a cup grease softened by paraffin oil, but bodied by such unctuous fillers as talc and lithopone. Sulphur is added, as it acts partly to keep the dies polished, and in this way reduces scratches on the work. However, it introduces other problems in lamp manufacture, to which I will refer later.

At critical sections where considerable drawing occurs, there is a tendency to objectionable stretch, but this is successfully offset by providing greater clearance. Strangely enough, although rustless steel sheets exhibit unusual work-hardening properties, the annealing operation preceding the operation on the expanding die may be eliminated entirely. At first it was necessary to anneal before forming the filler neck on the radiator but this was overcome by punching a larger hole before forming the neck.

Although the generally accepted principles of die design apply equally well to dies for rustless steel, there are a number of important differences disclosed by experience. For example, it was noted earlier that the large blank for radiator shells required double draw beads to allow the metal to flow freely without using excessive pressure which would cause breakage. Again, the abrasive action of rustless steel is so severe that additional clearance space between the walls of the die and punch is required. A clearance of 0.007 in. above the thickness of the metal itself seems best. Another variation of prime importance is that all working surfaces of drawing dies must be finished with a stone instead of an emery wheel; any slight inaccuracy or indentation of the surface will accelerate scratches and scoring of the die.

The drawing die and rings in the production of the radiator shell were made of close grained cast iron having the following composition: Carbon 3.25%, manganese 0.45, chromium 0.70, nickel 2.00, and silicon 1.25%. After machining, the die was heated to 1550° F. and oil quenched, then reheated to 900° F. and cooled in air. The final hardness was between 286 and 321 Brinell.

The drawing punch was made from a chromium die steel (non-shrinking and air-hardening) well adapted for the deep drawing of rustless steel. It was built up of sections seated in a cast iron punch shoe. The punch sections were preheated in a furnace held at 1350° F., transferred to another and allowed to soak at 1900° F. They were then removed from the furnace, hung on wires and cooled in air.



Finally, these sections were heated to 980° F. and held in the furnace one hour for each inch of section thickness.

Manufacture of Head Lamps

The production of head lamps is equally interesting and similar to that described above. The centers of the radiator shell furnished half of the lamp body requirement, but the balance came in as strip stock. We now receive it in the shape of flat disks punched by the mill to the correct blank size.

A progressive press, shown above, is used to form the head lamp shells. Stock in the form of disks is fed from a magazine, being lifted by suction cups. The production is about 18 shells per min.

In this forming operation quite different metal has been found advisable for both the die and punch. The former is made of high speed steel, as even the special alloy cast iron wears too much. The punch is carbon tool steel, hardened.

One point of great interest refers to the lubricant. Generally this contains considerable sulphur, but sulphur in a lamp plant is a real nuisance. If a particle of it lodges on the silver plated mirrors it makes specks of dark silver sulphide. For a time it was difficult to trace these defects to their source, but since removing sulphur from the draw lubricant the specks have disappeared.

The first press used was found to be inadequate for the job and much heavier ones were installed. Forming head lamps also requires draw beads and much heavier pressure on the draw ring than with low carbon steel sheet. This is necessary to prevent wrinkling, which can be very troublesome due to the work hardening of the austenitic chromium-nickel steel.

Sometimes the edges of semi-formed pieces would crack on standing without annealing. However, scrap losses have been reduced to 1% by proper handling.

The head lamp door is a stainless part that is actually made at a lower cost than the former brass door. Brass, rather than steel, was formerly used, partly because by its location it got more "polishing care" in hands of the average owner, so the plating was worn off and the door rusted quicker than the lamp body itself. In making the door of brass a large disk was used and the center was punched out. The center stock was in part salvaged, but the stock used was excessive in amount.

The present design uses a rustless steel strip which is butt welded into a hoop. The flash is then sheared off and the hoop formed into a door ring in a series of drawing opera-

tions. The most interesting of these is producing the barrel contour in the expanding press shown at top of page 24. In this a disk of rubber is used, which by compression takes a barrel shape and forces the steel out to the die. We make these rubber pads ourselves, carefully controlled as to hardness and strength. They last about 3 to 4 days in production.

In the case of the tail lamp manufacture we have an example of the necessity of annealing during fabrication. After the shell is drawn two holes must be opened and flanged, one parallel to the axis and the other at an angle. The first-mentioned hole offers no particular problem but one at an angle cannot be made without at least a local annealing. This is done with a blowpipe which softens about half an inch around this area.

Hub caps now take the largest amount of rustless steel in Ford operations. Former hub caps, smaller in size and without decoration in color, are not so interesting except to note that as with the present ones, it was necessary to reinforce them with a heavier backing of low carbon steel sheet.

The present operations are blanking from strip stock, drawing, trimming, flanging and pressing, assembling, spinning of the edges, washing and painting.

In the drawing no lubricant is found necessary but the blank must be held very snugly so as to allow no slip. Actually the gage of the metal is materially reduced. The punch and die are made of non-shrinking chromium steel. Operations at present are all done on separate machines. In trimming, the punch and die are made with very little clearance to give sharp shearing action, and are also made of the above-mentioned steel.

Material for the stampings described has been either 18% chromium, 8% nickel or the straight 18% chromium-iron. Either has previously been pickled at the mill, given a light cold rolling pass, and passivated by nitric acid dip. It has a clear, silvery gray appearance, ready for polishing and buffing.

Such sheets in the polished state should withstand several 100-hr. periods in the salt spray test without showing rust spots. I do not believe that any definite correlation between salt spray and actual service can be given without supposing some particular climatic conditions of exposure and service. We do, however, believe that good resistance to salt spray indicates longer probable life. It has definitely been shown that life of plated work in service and resistance to salt spray both increase with thickness of plate. It is therefore logical to believe that the enormously thicker layer of non-corroding metal has a very long life indeed.

Care must be taken to get good surfaces and steel of moderately small grain size, so as to avoid "orange peel" markings during the forming operations. These must be polished off — a tedious operation.

Physical properties which have been found satisfactory are as shown in the tabulation at the left of the engraving.

	18% Cr	18-8
Elastic limit	50,000	40,000
Tensile strength	75,000	80,000
Elongation in 4 in.	27% min.	50% min.
Erichsen cup	7.5	11.0 min.
Rockwell hardness	B-75 to B-80	B-75 to B-83

Result of First Draw on Oval Blank to Form Radiator Shell Was a Shallow Pan. Fifteen more operations on individual machines were required to make the part ready for polishing. Center portion cut out and formed surplus stock, useful for lamp bodies, hub caps and other parts

Two common steels develop approximately the same tensile properties in ½-in. rounds when quenched and tempered or when quenched in an appropriate hot bath. The latter procedure gives slightly lower ductility for equal tensile strength.

Quenching Steel in Hot Baths

Transformation of austenite at constant temperatures below the critical has been studied and reported by E. S. Davenport and E. C. Bain, and J. M. Robertson, among others. By microscopic study, magnetic analysis, and dimensional changes these men's researches aimed to establish transformation phenomena under what might be called ideal conditions. These conditions demanded specimens with large surfaces as compared to their mass.

The practical application of the facts developed by the above researches has been recognized. A. V. DeForest, in discussing Davenport and Bain's work, says, "I only hope that the authors will continue from the brilliant beginning — and tell us something of the physical properties, in other words, the practical aspects that follow this illumination. The practical man was quenching his wire in molten lead in the patenting process long before delayed transformation was even suspected" (*Transactions*, A.I.M.E., 1930). Taylor's precise instructions for the heat treatment of the newly discovered high speed steels were to quench them in a lead bath at 1150° F. and this practice still has numerous staunch adherents. Furthermore, nearly all supervisors have met at least one practical man who believes that best results on this or that variety of alloy steel can be secured by a correct cooling, rather than a drastic quench and draw back.

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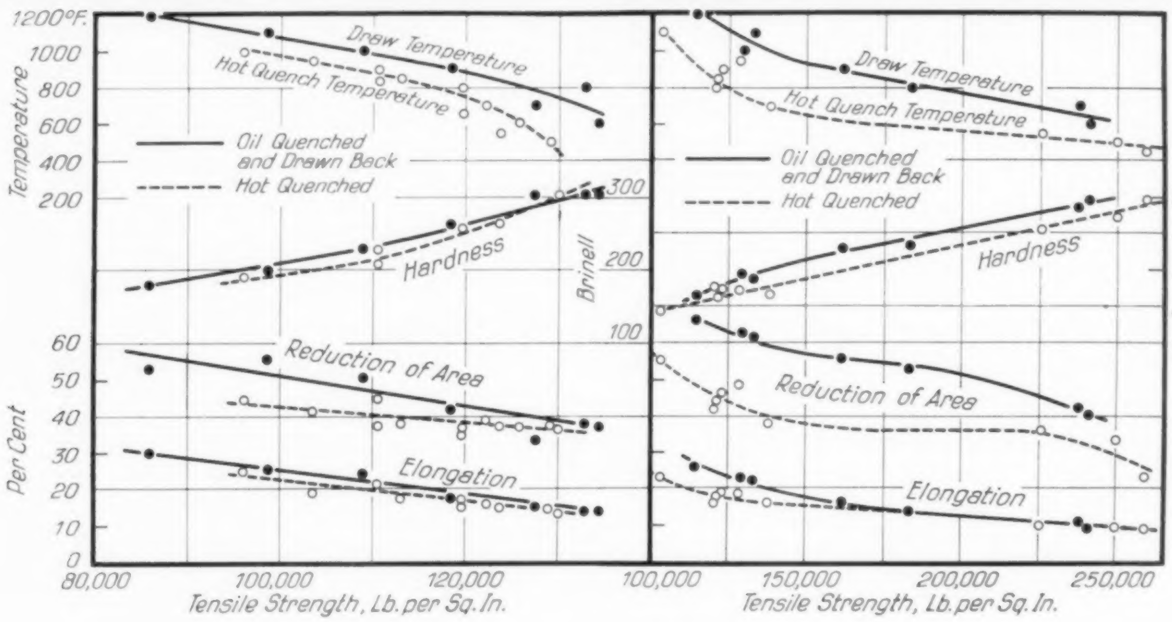
Robertson, in his paper before the British Iron & Steel Institute, 1929, says that hot-quenching and tempering of a cold-quenched steel may result in similar ultimate constitution in the two cases, but different crystallographic structures will be produced, accompanied by different properties. Davenport and Bain promised a study on "the fundamental difference between steels transformed at elevated temperatures and steels transformed to martensite and subsequently tempered or drawn back to comparable physical properties." This statement implies that equal physical properties may be secured by the two methods.

Kotaro Honda has reported to the A.S.S.T. in 1928 the results of certain physical tests on a eutectoid steel quenched in hot baths. He found that equal tensile strengths might be produced by the tempering of a cold-quenched specimen or by hot-quenching. However, the temperatures of tempering and of hot-quenching were different.

Studies by Germans

Scientists in Germany have studied the phenomenon as it relates to the normal transformation of austenite to pearlite, and an account



At Left Is a Comparison (on Basis of Equal Tensile Strength) of 0.505 x 2-In. Test Bars of S.A.E. 1045, Oil Quenched and Drawn Vs. Quenched in Hot Bath. At right are similar data for nickel-chromium steel S.A.E. 3130

of their findings, interpreted by metallographical theory, is given by Dr. Diergarten in METAL PROGRESS last March. Isolated experiments along the same lines with high carbon steel wire were reported by Dartrey Lewis and Hamilton Ferguson in April and September issues, respectively. Dr. Diergarten's own experiments show that nickel-chromium steel (approximately S.A.E. 3360 with 1% tungsten) will give the same hardness when quenched in various mediums at 650° F. to 300° F., and is unaffected by subsequent drawing. Straight carbon tool steel disks, on the other hand, gave him satisfactory hardness and fine fractures only when quenched in cold water.

Experimental Conditions

This paper is concerned with physical tests on three common steels heat treated by (*a*) the orthodox methods of quenching, followed by tempering or drawing, and (*b*) by what may be called for lack of better terminology "hot-quenching" methods. The steels studied include a plain carbon steel S.A.E. 1045, a nickel-chromium steel S.A.E. 3130, and a carbon tool steel of eutectoid composition. Test specimens (0.505x2 in.) were prepared before heat treatment. Heating periods of 15 min. above the critical temperature were adopted. Drawing or tempering periods and soaking times at constant hot-bath temperatures were uniformly 15 min. All samples were air cooled from tempering or hot-quenching temperatures. Data on physical properties were secured by tensile tests and Brinell hardness determinations. The work was done with the help of P. Berg, J. Mitchell, and C. Wetzel, students in the Mechanical Engineering Department of Iowa State College, Ames, Iowa.

Rather than list the numerical data in a table or plot the figures on conventional diagrams for physical properties, the curve sheets at the top of the page have been drawn to show the various physical properties (and temperature of draw or quench) plotted against tensile strength. These graphs show that for equal tensile strengths, the hardness and ductility values are slightly lower for hot-quenched specimens than for oil-quenched and drawn specimens. For equi-tensile strength, the hot-quench temperature is from 100 to 300° F. lower than the drawing temperature after an oil quench.

Data for high carbon steel are shown in the

curves at the right. Test values are slightly erratic (especially the figures for elongation) and only tensile strengths for various quenching media have been plotted.

Results on ½-In. Bars

The following conclusions may be made for ½-in. specimens tested. No information is available for other thicknesses of section.

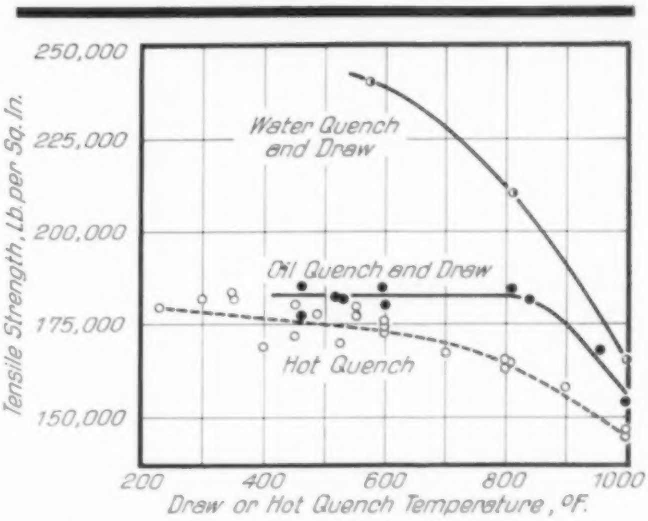
1. Tensile properties secured by tempering or drawing of a quenched steel may be approximated by hot-quenching.

2. On the basis of equal tensile strengths, hot-quenched steels were generally slightly lower in elongation and reduction of area (although little different in hardness) than the same steels treated by regular quenching and tempering.

3. For the duplication of tensile strength with the steels studied, temperatures of the hot-quenching bath are several hundred degrees lower than the tempering temperatures.

4. Since the maintenance and control of hot-quenching baths should be no more difficult than in the similar operation of tempering baths, the process of quenching into hot liquids might have certain practical applications. Hot-quenching should prove more economical than the double treatment of quenching and reheating, from the viewpoint of reduced handling costs, lower heat demand, lesser spoilage due to quenching strains, and deeper hardening.

5. Only individual cases have been studied. Logically, it would seem that a more complete investigation on other standardized steels would result in physical property charts such as have been developed for orthodox quenching and reheating.



Comparative Tensile Strength of Carbon Tool Steel Quenched in Different Media, Cold and Hot

Courtesy Republic Steel C

Editorial

Domestic Uses For Stainless

IMPORTANT uses of stainless sheet and strip which received much publicity have lately shrunk to less conspicuous importance — particularly the use as trim on skyscrapers and automobiles. The first mentioned is stopped except for modernization of store fronts; the second has encountered serious competition from better chromium plate, and restriction by style.

Fortunately, some new applications of less spectacular nature have arisen to fill the gap. One or two are especially worthy of comment, since they apply to home equipment (and therefore have a very large potential market) and have either been adopted because of lower over-

all cost or because the appliance would not operate without corrosion resistant steels.

One of these is the cooling unit for domestic refrigerators. Essentially these consist of a pair of small receivers into the bottom of which is welded a series of tubes, bent into U shape, for circulation of the cooling medium. The entire unit has to be absolutely tight against leakage of penetrating refrigerants, and on the outside must be made stain proof and easy to clean — either by selection of proper material, by metal coating, or by enameling.

An interesting alternative (already adopted as standard by one of the principal makers) is made of a pair of 18-8 sheets pressed out so that when laid one against the other the necessary receivers and circulating channels are formed. Seam welds are then run between the channels and around the folded-over edges and the cooling unit is complete. The metal resists inside corrosion, and its mill-polished surface needs no further preparation outside. Shop costs are so much lower that the saving more than counterbalances the higher cost of the expensive alloy steel sheet used as raw material.

The other modest application, which aggregates a very important tonnage, is of high chromium-iron sheet for range-oil burners. Although they were invented 35 years ago, their use was restricted because the enameled iron burners would warp or scale after two or three months' intermittent service. When heat resistant chromium steel sheet was utilized they attained instant success. Sales amounted to only a few thousand in 1928. By 1930 it ran up to 100,000 and no less than 285,000 installations were made last fall.

A representative design has two annular troughs for the fuel oil, about 6 in. diameter. This supports a nest of four concentric cylinders, 5 in. high and spaced about $\frac{3}{16}$ in. clear, one inside the other. Each cylinder is of chromium-iron sheet (about 22 g., with scarfed spot-welded joint) riddled with $\frac{1}{16}$ in. holes.

The outer two cylinders form a chimney above the outer trough containing fuel oil, and the inner two cylinders form a corresponding chimney for the inner trough. Air is aspirated up between, through holes in the bottom casting. An asbestos ring is placed in each groove for easy lighting. In operation, innumerable jets of air are surrounded by an atmosphere of vaporized oil, and the chromium-iron sheets reach a temperature of 1750° F., where radiation from the steel replaces radiation from a carbonaceous, smoky flame.

New England is a logical place to sell such equipment, for coal is dear, wood is dearer, and natural gas non-existent. However, "range oil" (the modern counterpart of kerosene) can be produced at byproduct prices which will compare favorably in cost with other fuels anywhere on a B.t.u. basis. Hence the market is by no means restricted, either to New England or to cooking ranges. Built-in water heaters, "base burners" of attractive design, and even house heating furnaces using range oil are making their appearance.

Here is an expanding market where special alloys need fear no competition.

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Expensive Electricity

IT IS an agile man who can buy his required heat to best advantage these days. Many are finding that the economics of spasmodic production are entirely different from those of continuous operation at a sizable percentage of capacity. Another complication is due to the recent entrance of natural gas into many industrial regions, or the shipment of cheap butane in tank car lots. Developments of new refractories, insulation, gas atmospheres, and special furnaces have all had a hand in dislocating the balance which existed only a year or two ago.

Plants operating electric melting furnaces are meeting this situation in its most muddled form. Owing principally to stand-by or demand charges and penalties for lagging power factor, such operators find themselves paying exhorbitant rates for very little current. For instance, one large foundry melting cupola iron found that three heats in its 3-ton electric furnace would have cost $1200.

While this is an unusual instance of the effect of short overloads on a bill for electric power, jobbing steel foundries reported to the last meeting of the American Foundrymen's Association costs for electricity ranging from 20 to 30% of the selling price of the castings. In all

these cases more than half the bill represented a demand charge. Power companies justify this by saying that they must collect for overhead on plants and distributing lines built to be "ready to serve," but this finds little response from a manufacturer who views his own idle capacity, also built in readiness to serve, for which he can charge his customers nothing.

Before this unequitable situation can be corrected, it is likely that many foundrymen will rediscover the fact that excellent steel can be made in a converter, and let someone else take the business that just *must* be melted in an arc furnace.

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Send in Your Old Handbook

WE, in the National Office, are proud of the job done by the Society's Recommended Practice Committee, J. E. Donnellan, Secretary of the Committee, and the Data Sheet Committee of the Institute of Metals Division, A.I.M.E., in producing the 1933 Edition of National Metals Handbook. All the more are we surprised that the members of the Society are so slow in trading in their old, obsolete handbooks for the brand new edition.

All it costs is the postage on your old handbook. What you get is a new volume, half again as large as the 1930 edition, thoroughly revised and right up to date. Worth $10 of anyone's money! *But*, you must send in your old book to get the new one. So why delay?

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'Ware the Old "Sample" Game

THIS booby trap has been laid so often for the unwary that everyone ought to know about it and be wary, but some smooth foreign gentlemen have reappeared on the scene with the old, old trick. Evidently they think there is a chance for a killing, and their judgment should be respected. So this is what to avoid:

Avoid listening to a stranger with a story about a wonderful new steel or alloy which will do about everything you could wish for, and certainly will correct the one particular difficulty which is troubling you at the moment. (No one knows how this plausible stranger finds out your latest trouble, but he generally guesses it aright.) He may have a foreign accent and represent an importer or a foreign mill—that is not strictly necessary for his game, but his firm will always have an unfamiliar name or preferably one cleverly approximating that of a reputable manufacturer.

Avoid signing an order for a sample of the material, unless the dimensions of the sample are indelibly written on the requisition! For if you do, the "sample" when it arrives will be a long bar or big billet costing you quite a bit of money at the fancy price per pound, and prove to be nothing more than the commonest grade, to be got at any warehouse at a fraction of the amount.

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Unscrambling Mixed Steels

SOMETIMES a purchaser may raise a question "How do I know whether these parts are really of stainless steel?" or a producer may suspect that a few pieces of carbon steel have been mixed with stainless. How can a quick separation be made without damaging the expensive metal?

A simple method is used by Lamson & Sessions Co., as described by Mr. Peterka in his article in October (page 35). It was originally devised to test the adequacy of final cleaning and passivating of stainless screws, rivets, and bolts. In turn it dates back to the idea that genuine "stainless" cutlery steel will not deposit copper from a sulphate solution.

It is a modification of the well-known Preece test for galvanized sheet. The regulation solution (36 parts of copper sulphate crystals to 100 parts of water) does not need to be neutralized with cupric oxide — for the acidity does not harm high chromium alloys and the black oxide which would settle on the surface would have to be scrubbed off before the copper can be seen.

If suspected parts are dumped in such a solution for a couple of minutes, common steel comes out looking like red copper, whereas stainless retains its original silvery sheen.

Bakelite is an ideal mounting material for specimens which are unaffected by pressure or heat up to 355° F., but the curing press has heretofore been too expensive for many laboratories. Here is a home-made device which works, and (aside from labor and an automobile jack) costs little or nothing.

Press and Technique for Mounting Small Specimens

Preparation of the polished surfaces of small specimens, metallic or non-metallic, for microscopic examination is impossible without the aid of a supporting medium. The object of this paper is to show how simply and well bakelite fulfills the requirements, and also how cheaply the required press may be constructed. The application here described applies only to pieces too small to be held by the hand; for extremely fine particles, about forty mesh or finer, a modified technique from that to be described must be used.

Use of bakelite for the purpose is not new. Some well-equipped laboratories have hydraulic presses and a complete set of auxiliary equipment for mounting specimens of wire and wire products, sheet metal stampings, shot, and other small or fragile materials. Such a special press, however, is relatively costly, and the particular reason for granting space to a paper such as this is the interest recently shown in our quite inexpensive press during the summer school for teachers in mining and metallurgy held at the University of Wisconsin. The only purchased part was the hydraulic jack, and this is of the type commonly furnished in an automobile repair kit, and hence can be picked up new or second-hand for a few dollars.

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The grade of bakelite used is known as "Black Bakelite AM-261." It has the property of adhering tenaciously even to smooth specimens, not permitting them to be broken loose from the mount when polishing and consequently giving good margins between specimen and bakelite. Good margins eliminate crevices which retain abrasive particles.

The only undesirable features of the method to be described (and these are of no moment except when mounting some hardened, not tempered, steels and the low melting point alloys) are the necessity of heating the specimen to 355° F. and exerting a pressure of approximately 2000 lb. per sq.in. on the mount. If the specimen is not affected by these conditions, bakelite is the most satisfactory mounting material to be had.

It is resistant to all common reagents and to alcohol, is quite hard and does not give much trouble because of relief polishing. It can be marked easily and thus small specimens which cannot be marked, may easily be tagged for future reference when mounted in it. It has considerable strength. It grinds and polishes to a smooth surface. It is relatively inexpensive, since it is light and the quantity used in mounting a single specimen is small.

The complete apparatus set up for operation is shown on the next page. The press con-

sists of the hydraulic jack *H.J.* fastened to an iron base plate. This base is equipped with feet and screwed down to a wooden base or table top for greater stability. Two round iron rods are screwed or welded into the base and set far enough apart to straddle the platform on the jack, which is notched so that the vertical rods act as guides. The top ends are fitted with two nuts to hold the fixed plate of the press in position. Transite board, about 6 in. square, is used as heat insulation above the jack and below the upper fixed plate. The latter are drilled to pass an ordinary mercury thermometer *T*, reading to 500° F.

The handle of the pump is hooked at its end, to which weights are hung. Two weights are used, *W-1*, which gives a pressure of about 150 lb. on the mold, and *W-2*, which gives a pressure of about 1650 lb. on the mold. The use of the two weights will be explained later.

In describing the heater, *H.E.*, no dimensions will be given, as they can be varied to suit individual requirements. It is merely a thick-walled aluminum casting; it contains a coil of 22-g. nichrome wire for a heating element. Enough of this wire to give a resistance of 40 ohms was closely wound on a ⅛-in. rod and then pulled out to break contact between turns. This "spring" was then wound in a helix around a paper-wrapped graphite cylinder about ¾ in. larger in diameter than the required cavity in the heater.

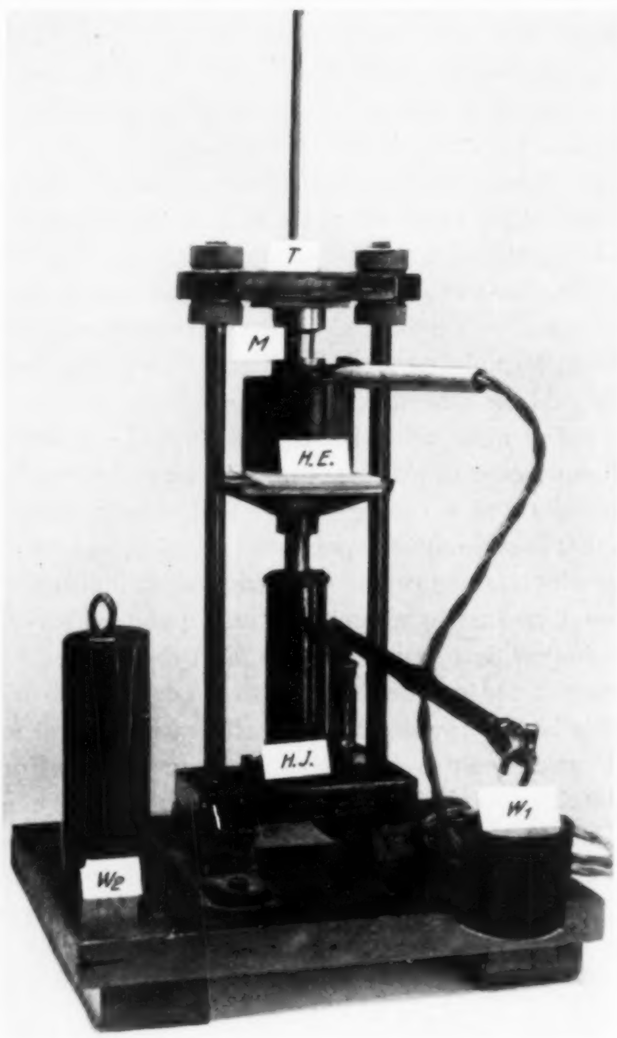
A thin paste of alundum cement was then forced into the coil of nichrome and the outside completely plastered. The entire assembly was then dried and fired to 1800° F. to harden the cement. The heating element was then removed from the graphite core and the inside of the heating element was given a thin plastered coat of alundum cement. Insulators were also cemented on, through which the leads from the coil are to be brought out of the aluminum block. The coil was then dried and fired a second time.

As before mentioned, the heater is merely a thick-walled aluminum cup. Its inner diameter and depth are chosen to accommodate the steel molds to be used. Its walls are about an inch thick — enough to embed the above described heating element in the center.

A pattern for the aluminum casting was then rammed up, and the heating element was set in the mold and held in position by aluminum wires. The cold casting was machined, and equipped with a segment of transite for a binding-post strip, and terminals placed for the electric cord. A convenient handle was also attached, which has the additional function of anchoring the lead-in wires.

This heating element consumes about 240 watts and is entirely adequate for the purpose intended. The time necessary to mount a specimen could be cut in half by embedding two heating elements in the aluminum casting, one as described above and another in the base, coiled in a spiral like the heating element of an ordinary hot plate.

The mold in use at the University of Wiscon-



Home Made Press ($5.00 for New Material), for Mounting Small Specimens in Bakelite

sm was machined from 2-in. steel shafting. Parts are illustrated at the right. *M-2* is the bottom; it has a shoulder around its edge to fit snugly about the mating part at the lower end of *M-3*. *M-1* is a small disk which fits into the open bottom of *M-3*; it may be drilled with shallow holes to keep specimens such as steel shot from rolling about. *M-3* is drilled end to end to pass the plunger end of *M-4* (shown standing on its head) in a sliding fit. If too much clearance is allowed the bakelite will squirt back. A ¼-in. hole was drilled from the top of *M-4* down its axis about 80% of its length to accommodate the thermometer. The entire mold assembly fits into the aluminum heater.

Bakelite shrinks to about 40% of its original volume at a temperature of 140 to 175° F. During the shrinking period, when it becomes plastic, a low pressure is applied. As soon as the flowing or shrinking has ceased, the pressure should be increased rapidly to the maximum. The operation therefore consists of two periods, plastic flow and curing.

The bottom of the mold *M-2* is set on a table and plate *M-1* placed in the center. The specimen or specimens to be mounted are placed on the latter, and cylinder *M-3* put in place. Fifteen grams of the bakelite is placed in the mold and the plunger *M-4* pushed in place and squeezed down by hand. The entire mold assembly is then placed in the heating unit by up-ending it and pushing it up into the inverted heating unit *H.E.*

This heater has previously been plugged in and brought up to temperature, which takes about 10 to 15 min. (If not connected beforehand, it just means that a longer time will be required to mount the first specimen.)

Heating unit and mold are then placed upright on the very center of the movable plate, the press closed, and the thermometer placed. The small weight is hung on the end of the pump handle. During the first or shrinkage period the apparatus must be watched; the external indications are a continuous dropping of the pump handle. If this should fall to the bottom of a stroke, it must be immediately raised to the top position and weight replaced.

When shrinkage has ceased, the small weight is removed and the heavy weight put in its place. It is important that this be done promptly — perhaps just as the handle is ceasing its downward motion. No further attention need be given to the apparatus until the temperature is indicated as 355° F., whereupon the molding operation is complete.

Heating unit and mold are then removed from the press and the mold dumped in a pail of cold water. It will be found quite easy to separate the mold; the bakelite mount will be shrunk on the bottom of the plunger but can be readily twisted off. The mold is then wiped dry and the cycle is repeated. If a number of mounts are to be made, the electricity can remain connected.

Unit Parts of Mold and Heater. S_1 shows the back of a bakelite mount, smooth and easy to clean. S_2 to S_5 are clock gear, brass bolt, chalcopyrite, and steel shot respectively, mounted and polished. Excellent adherence is evident; lack of margins or relief polish is characteristic

Troubles: If the mount looks rough, too much pressure was applied during the stage of plastic flow and shrinkage. If the mount seems to be attacked by alcohol, the bakelite was cured too short a time or at too low a temperature. If the bakelite sticks to the mold and leaves a rough surface, the pressure was too high at the beginning of the molding operation.

Platinum has given way to tungsten and molybdenum (and some copper) adequately degassed by long heating in hydrogen so no gases will be evolved during operation to impair the vacuum and hence the functioning of the tube.

Gas-Free Metals Used In X-Ray Tubes

Röntgen discovered the X-rays in 1895 from a funnel-shaped Crookes tube which had an anode flush with the side wall and a flat cathode at the small end. The cathode rays impinged on the broad end of the glass tube, and there set up the unknown rays. This simple device was greatly improved by Campbell-Swinton, who introduced a platinum target, and by Jackson, who put in a concave aluminum cathode for focusing the rays. A later step of great importance was the addition of a device for regulating the vacuum of the tube.

The thin metal target was soon replaced by a heavy mass of metal consisting essentially of two parts, a refractory metal face to take the cathode-ray impact and a heavy backplate of some good heat conducting metal. Platinum and copper came into general use for these purposes. The platinum facing was made very thin, about 0.001 in. thick, and was attached to a disk of nickel which, in turn, was soldered to a large mass of copper. The tube had a very definite energy limitation; and if this were exceeded, even for an instant, the thin facing of platinum was ruined at the focal spot. This was the general situation as it existed about 25 years ago.

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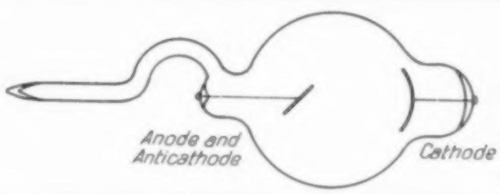
In a paper given by the present authors before the International Electrical Congress in Paris, from which this account is extracted, developmental work on incandescent lamps was described which started in 1905 in our laboratory. This led us later into the field of X-ray tubes. It began with an investigation of metallic tungsten, and resulted first in its production in a ductile form, and finally in its application for various purposes, among others, its use for both electrodes of the X-ray tube.

Up to this time, tungsten had always been a brittle metal — as brittle as glass — and not workable. As a result of laboratory efforts extending over several years and involving many men, it became possible to produce metallic tungsten in a ductile form. At the risk of repeating something that is well known to a few metallurgists, it may be said that the process is unique in this respect, among others, that it does not melt the metal. This has never been feasible for the reason that there is no suitable material from which the crucible can be made; fireclay would vaporize far below the melting temperature of tungsten (about 6150° F.).

The process starts with wolframite (an ore consisting of iron, manganese, tungsten, and oxygen) from which the yellow oxide of tungsten is extracted and then highly purified. This yellow oxide is next reduced to metal powder by heating it electrically in a porcelain tube

through which a stream of hydrogen gas is passing. A very careful and exact control is necessary, so that the resulting tungsten particles shall have the proper size.



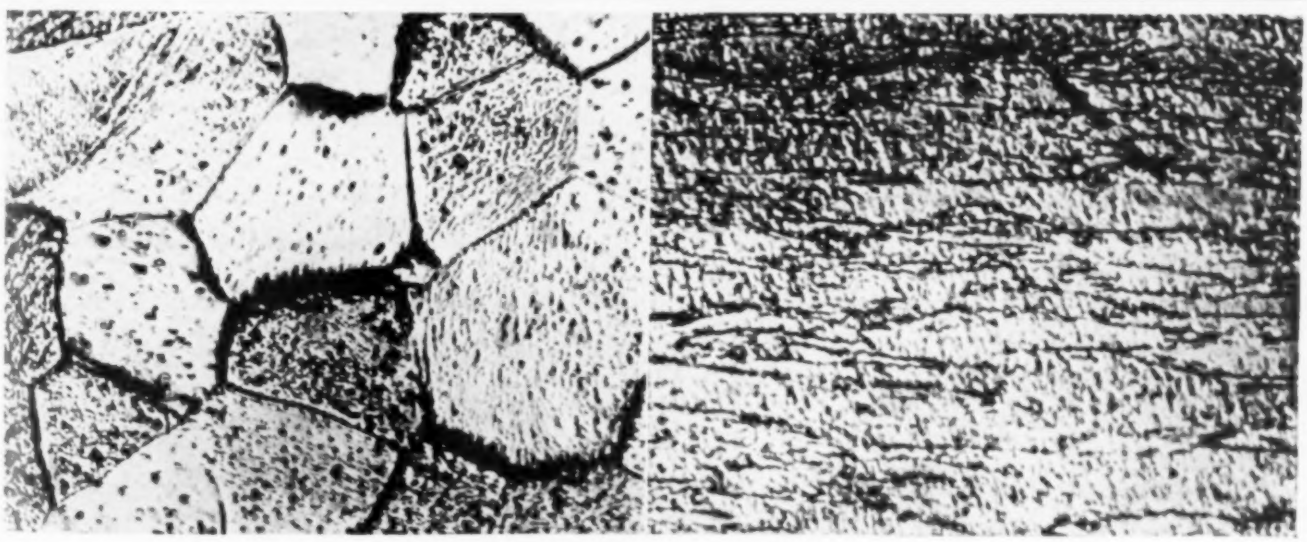
Sketch of Jackson's First X-Ray Tube. Electrons from concave cathode are focused on platinum target, which they penetrate slightly, giving up their energy as heat, one or two thousandths of which reappears in the form of X-rays

The dry tungsten powder is next formed under heavy pressure into rods and these are then heated electrically almost to the melting point in hydrogen. The resulting ingots are brittle when cold, but with care can be mechanically worked when hot. As the working proceeds the individual crystals are elongated into "fibers". With sufficient working, the resulting material becomes ductile and very strong when cold.

After the ductile tungsten process had been developed sufficiently for the needs of incandescent lamp manufacture, the next application found for it was as the target of the gas-filled X-ray tube, in place of the platinum which had previously been used. For this application, sheet tungsten was required, and it was found that this could be produced by hot rolling the hammered rods. Small disks required were punched from hot strips.

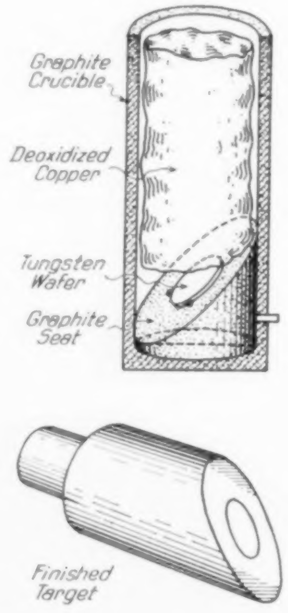
The next problem — and it caused a delay of many months — was to find a method for attaching a disk of tungsten to the block of copper forming the remainder of the target. It finally was done in the following manner: The surface of the tungsten is first carefully freed from oxide. Copper which has been freed of its oxide by treatment with boron is then cast in a vacuum onto the tungsten. The copper then wets the surface of the tungsten, and the result is a union of very high thermal conductivity.

The practical means employed for carrying out the vacuum-casting operation are shown in the sketch on page 38. A cylindrical graphite crucible is made having a removable graphite piece in the bottom to serve as a temporary support, at the desired angle, for the tungsten disk. The latter is kept in place by three little molybdenum pins. A block of boron-treated copper is then placed in the crucible, and the crucible and its contents placed, together with others, in a vacuum furnace. The temperature is raised slightly above the melting point of the copper; if too high, the tungsten will lose its strength acquired by mechanical working and the target will crack badly in use.



Micros of Coarse Crystalline and Fragile Tungsten Before Swaging, and "Fibrous" Structure Afterward When It Has Been Strengthened and Toughened by Cold Work

Graphite Crucible and Support for Casting a De-oxidized Copper Block on a Tungsten Wafer



For the best anodes the target of tungsten must not be too thin, for otherwise the copper will melt back of the focal spot when it is bombarded with electrons, and will, by its expansion, bulge out the tungsten at this point, leaving a vacuous space under the tungsten and spoiling the good heat conductivity between the two. As copper conducts heat better than tungsten, it is, on the other hand, better to have the tungsten disk no thicker than is necessary to avoid the melting of the copper under the focal spot.

The advantages of ductile tungsten over platinum for the target face are its higher melting point, lower vapor pressure, and greater heat conductivity. Its use made possible the production of much higher X-ray intensities from a given size of focal spot. Trial targets consisting entirely of tungsten were also made for the gas tube, and, in competition with those of solid platinum, they were capable of radiating much greater amounts of energy from a given surface area.

Before the advent of the hot-cathode tubes, the tungsten target had replaced platinum in the high power radiographic tubes.

Development work on the copper-backed tungsten target brought with it interesting experiments with gas-filled X-ray tubes. Large amounts of energy were passed through these tubes to show which kind of target best withstood abuse. Upon overloading the focal spot, the tungsten vaporized and this brought about very rapid changes in gas pressure.

Dr. Langmuir found that tungsten vapor unites quantitatively with nitrogen; hence any nitrogen gas was removed as such and deposited as solid nitride on the walls of the tube. Oxygen reacted with hot tungsten to form a solid oxide of tungsten which was also deposited on the bulb. Hydrogen, argon, and helium also disappeared in time; while they do not react with hot tungsten or with tungsten vapor they are probably trapped under the tungsten depositing inside the bulb when the tube is overloaded.

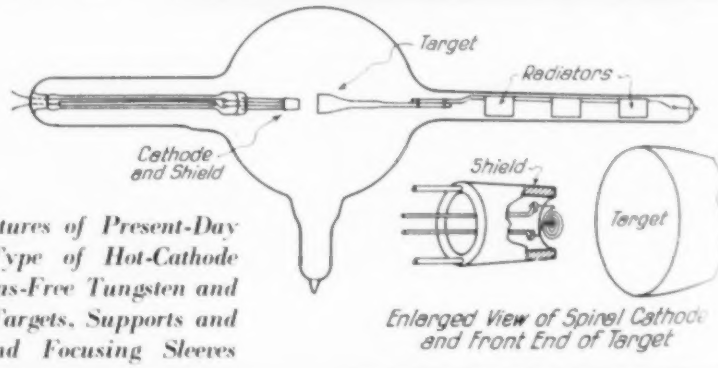
Another trouble then made its appearance. The aluminum cathodes melted. To obviate this, a tungsten cathode was tried. This made the tube exceedingly "cranky." One would no sooner get it started than it would refuse to carry current until more gas had been introduced.

The extreme instability attendant upon the use of cold tungsten cathode (in what was otherwise a standard X-ray tube) called attention forcibly to the part played by the gas contained or absorbed in the ordinary aluminum cathode. (The tungsten cathodes were relatively gas-free.)

Metal for Hot Cathode

It is impossible here to review all the work which led to the solution of this problem of electron emission from hot tungsten filaments. Some experimenters believed that no current would flow from a hot cathode which had been completely freed from gas, but Langmuir found that the electron emission not only persisted in high vacua, but was favored by getting rid of the last traces of gas in the metal filament.

The same method was tried with the X-ray tube, and it was found that here also,



Principal Features of Present-Day "Universal" Type of Hot-Cathode Tube, Using Gas-Free Tungsten and Molybdenum Targets, Supports and Conductors, and Focusing Sleeves

even with the much higher voltages and the much larger masses of metal, it was possible to get and to maintain vacua in which the phenomena were stable and reproducible.

The idea of using a hot cathode in an X-ray tube was not new, but the principle had never been successfully applied in such a good vacuum that positive ions did not play either an essential or a harmful role.

In the first "Coolidge" tube the cathode consisted of a spiral filament mounted behind a

Of all the matters which together are responsible for the present excellence of X-ray tubes, the only one of more than passing interest to metallurgists is the metal inside it. A solid tungsten target is preferable to a composite one for high power tubes. This gets rid of its heat by radiation. In order to prevent too much heat from flowing back into the anode end of the tube and affecting the seal and lead-in wires, the target should be merely wired to its support. The latter is a molybdenum strip

perforated focusing disk, both of tungsten and set in the cathode side-arm. The anode consisted of a circular tungsten disk attached to the end of a tungsten support-rod. From the earliest form, the design changed to that of the figure at the bottom of page 38, which is essentially the present "universal" tube.

Experience has shown that the hot-cathode tube has many advantages over the gas tube, and tubes of this type have now been developed to cover a wide range of usefulness. They vary in size from the oil-immersed dental tube, which has a bulb diameter of 1.5 in., up to a 900,000-volt tube having bulbs of a diameter of 20 in. A photograph of a recent design with an external finned radiator is reproduced above, by courtesy of the General Electric X-Ray Corporation.

riveted to some split rings of molybdenum fitting snugly into the glass. As the current is increased, a tube with a hollow water-cooled anode generally is to be preferred.

When a tube is operated on interrupted current, as from the induction coil or transformer, there is a very pronounced tearing of metal at and close to the focal spot. This is because of alternating expansion and contraction, due to the heating effect of the electron bombardment and the subsequent cooling as the heat flows to the adjacent metal. Even on a water-cooled anode that never gets hotter than 700° C., the target will tear to a depth of 1/4 in. in perhaps 100 hr. This may be prevented by avoiding too steep a temperature gradient in more massive targets and larger focal spots until the forces of expan-

sion and contraction do not exceed the elastic limit. Two other methods are available. One is to use direct current at constant potential, rather than interrupted current, but this involves a very considerable increase in cost. The second is to rotate the target so the cathode rays strike different places, whereupon the energy input can be increased several fold.

When the focal spot is at the melting point, the direct radiation amounts to only 1% of the total energy input. The large bulk of the energy must, then, be conducted away from the focal area through the adjacent metal. This accounts for the superiority of a copper-backed target. In tubes having solid tungsten targets, the major portion of the heat is removed by radiation from the body and stem of the target.

As the current is increased, the tube with a hollow anode, in general, behaves better than the one with the solid anode. In case the focal spot is overloaded, the metal vapor produced does not get to the glass envelope, nor do the ions resulting from this metal vapor cause a runaway effect.

As the efficiency of X-ray production increases with the atomic number of the target metal, it seemed worth while to try targets of metallic uranium and thorium. The gain proved to be very slight, however, and more than offset by the relatively low melting points of these metals and by the fact that traces of their vapors condensing on the hot cathode increase its electron emission enormously and so tend to promote instability.

Degassing the Metal

In the use of suitable electrode materials and thorough preliminary degassing, our work has been greatly assisted by that of Dr. A. L. Marshall who has heated samples of various metals in a very high vacuum, and collected and analyzed the gas given off at different temperatures up to 1800° C.

In the case of molybdenum, for example, Dr. Marshall finds that each time, as the temperature is raised, there is at first a rapid evolution of gas, followed later by a marked slowing down in the process. There would be, in general, no complete degassing at the lower temperatures, no matter how long the time. At about 1800° C., Dr. Marshall gets complete degassing of molybdenum, or at least as complete degassing as can be attained by thermal treatment. The composition of the gas given off at different temperatures varies greatly. Details may be found in *Transactions*, A.I.M.E., 1932.

He finds that the time required for complete degassing of a molybdenum sample is, within the experimental error, a linear function of the thickness, showing that the process is not confined to the surface but extends throughout the specimen. The gas content of a metal is largely dependent on the metallurgical processes which have been used in its production. That such preliminary heat treatment in high vacuum is of great practical importance is indicated by an experiment in which Dr. Marshall takes a sample of molybdenum which has first been completely degassed and then brought out into the air and handled. Upon heating this specimen to 1600° C. in a vacuum, it gives up the gas, which it has acquired, immediately. Gases absorbed during exposure to air are therefore confined entirely to the surface.

Tubes having solid tungsten anodes show, in general, a slight improvement in vacuum during the first few minutes of operation after they are sealed off from the pump. During subsequent normal operation there is, as a rule, nothing in their behavior throughout their life to suggest either improvement or impairment of vacuum.

If, however, such a tube is badly overloaded, even for a small fraction of a second, the vacuum may be so seriously impaired that the tube is no longer useful. It seems probable that when the tubes having solid tungsten anodes carry continuously more than a certain load, the inner surface of the bulb becomes so hot that there is some electrolysis of the glass, with consequent increase in gas pressure.

With tubes in which the target consists of a tungsten button set in copper, marked changes in vacuum may occur with use. If the target as a whole is allowed to get red hot, so much gas may be liberated from it that the vacuum becomes too poor for the continued safe operation of the tube. If the target is then cooled, it will, in general, be found that the gas is quickly taken up by the copper and that the tube operates as it did in the first place.

Relative Corrodibility of Some Common Metals and Alloys

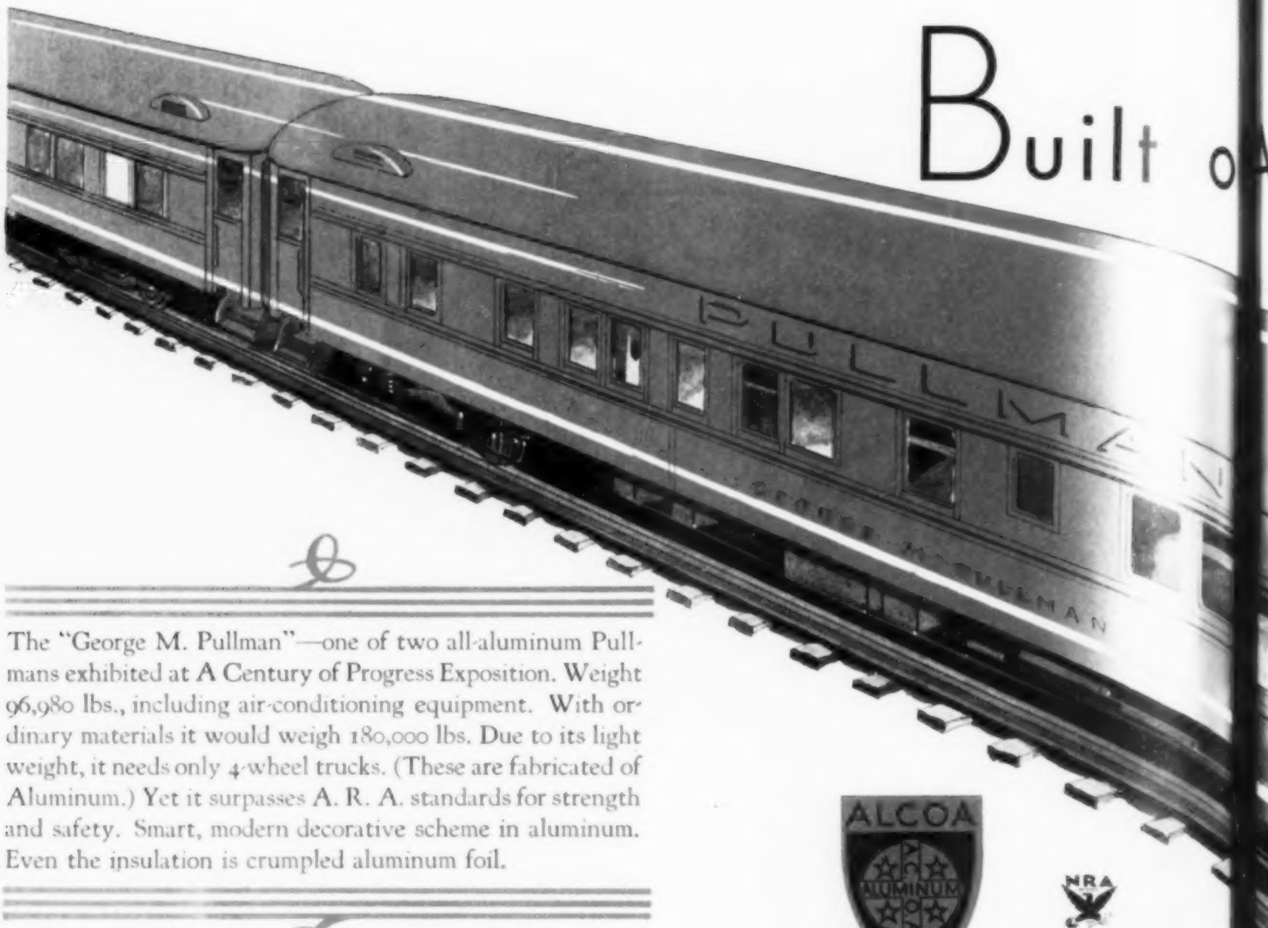
Class of Material	Nominal Composition: Carbon	Chromium	Nickel	Silicon	Copper			Atmospheres: Sea Shore	Industrial	Water: Domestic	Mine	Sea	Saline with H_2S	Brackish with MCl	Wet Steam	Oxidation Resistance, Max. Safe Temp. °F.: Oxidizing Gases	Reducing Fuel Gas	Sulphur Rich Gas
Ingot iron or wrought iron	0.03				0.08			P	P	P	P	PF	P	F	F			
Low C steel	0.10				0.08			P	P	P	P	F	P	F	F			
Low C copper steel	0.10				0.25			F	G	P	F	F	P	F	FG			
Hot galvanized iron & steel								G	G	F	F	G	F	F				
Calorized iron & steel								G	G	P	P	P				1650	1650	1650
Grey cast iron	2.8 graphite, 0.7 combined carbon							F	G	F	F	F						
High silicon iron	0.60			14.25				E	E	E	G	E						
Nickel cast iron	3.30		3.50	1.50				F	G	P	P	F						
Chromium cast iron	2.50	25.00		2.00				G	G	G	G	FG				1800	1800	1800
Ni-Cr-Cu cast iron	3.00	2.00	14.00	1.50	6.00			G	G	G	G	G	F	F	G	1200	1200	1200
Nickel steel: Low Ni	0.18		3.00					F	F	F	P	F						
High Ni	0.30		28.00					G	G	G	FG	E						
Chromium steels: 5% Cr	0.15	5.00						F	F	F	P	P	P	P	F	1200	1200	1200
12% Cr	.10 max.	12.00						G	G	G	F	F		F	G	1400	1400	1400
17% Cr	.10 max.	17.00						G	G	G	G	G		G	G	1600	1600	1500
17% Cr, 4% Mo	.10 max.	17.00				Mo 4.0		G	G									
27% Cr	.50 max.	27.00						G	G	E	G	G		G	E	1900	1900	1800
Silcrome, (8% Cr, 3% Si)	0.45	8.25		3.50				G	G	F	F	F	F	F	F		1500	
Stellite	3.0 max.	30.00				Co55.0	W15.0	E	E	E	E	E	E	G	E	2000	2000	
Cr-Ni steels: 8-20	0.20	8.00	20.00					G	G	G	G	G				1600	1600	
18-8, 4% Mo	0.15	18.00	8.00			Mo 4.0		E	G	E	G	G	E	E	E			
18-8	0.10	18.00	8.00					E	G	E	G	G	E	G	E	1550	1550	300 to 1300
18-12	0.10	18.00	12.00					E	G	E	G	G						
18-35	.50 max.	18.00	35.00	1.00				E	G	E	FG	G				1900	1900	1900
25-12	.25 max.	25.00	12.00					E	G	E	G	G	E	G	E	2100		
26-24	.15 max.	26.00	24.00	3.00				E	G	E	G	G	E	G	E	2100	2000	
Commercially pure Ni			99.20					E	G	E	G	E	G			1300	2000	P
Nickel alloys: Monel metal	0.15		67.50	0.50	28.50	Mn1.50		E	G	E	PE	E	G		E	900	2000	P
Nichrome, 60-15	0.12	15.00	60.00					G	G	E	G	G				1475 to 2100		P
Inconel, 14% Cr		14.00	80.00			Fe 6.0		G	G		G	G				2000	2000	
80% Ni, 20% Cr		20.00	80.00					G	G	E	G	G						
Hastelloy		14.00	58.00			Mo 17	W 5.0	E	E	E	G	E	E	E	E			
Commercially pure Cu					99.90			G	G	G	FG	G						
Copper alloys: Red brass					85.00	Zn15.0		G	G	FG	FG	G						
Tobin bronze					60.00	Zn39.2	Sn.75	G	FG		F	G	F					
Phosphor bronze					95.00	Sn 5.0	Zn1.5	G	FG		F	G						
Silicon bronze				3.00	95.00	Mn1.0 or	Sn.5	G	G		FG	G						
Aluminum bronze					90.00	Al 9.0	Fe.5	G	G		FG	G						
Nickel silver			20.00		75.00	Zn 5.0	Ni.5	G	G		G	G						
Admiralty metal					70.00	Zn29.0	Sn1.0	G	G		FG	G						
Commercially pure Al						Al 99.20		F	F	PG	P	F						
Commercially pure Sn										E								
Commercially pure Pb					0.06	Pb 99.90		G	G	PG	G	G						

Class of Material	Fruit, Vegetable Juices	Dairy Products	Other Food Products	Acids, Moderate Concentration 5-15%: HCl	H_2SO_4	HNO_3	Acetic	Phosphoric	Alkalies: 1 to 20% Sol.	Fused	Salt Solutions, Medium Concentration: NH_4Cl	$MgCl_2$	$MgSO_4$	Hot Sulphite Liquor	Dye Liquor	Refinery Crudes Below 400°F.: Sweet	Sour
Ingot iron or wrought iron	P	P	P	P	P	P	P	P	E		P	F	F			F	P
Low C steel	P	P	P	P	P	P	P	P	E		P	F	F	P		F	P
Low C copper steel	P	P	P	P	F	P	P	P	G		P	F	F	P		F	P
Hot galvanized iron & steel	P	P	P	P	P	P	P	P	F		P	P	PF				
Calorized iron & steel														P	F	FG	FG
Grey cast iron	P	P	P	P	P	P	P	P	E	F	P	P	P	P	P	F	
High silicon iron	G†			F	E	E	G	G	E		G	G	G	P			
Nickel cast iron									E	FG				P	P	F	
Chromium cast iron																	
Ni-Cr-Cu cast iron	F			F	F	P	G	G	G	G	F	F	F	F	F	G	G
Nickel steel: Low Ni	P	P		P	P	P	P		E	G	P	F	F				
High Ni	F			F	G	P	P		E	G	F	E	E				
Chromium steels: 5% Cr	P			P	P	P	P	P	G		P	P	F	P	P	G	G
12% Cr	G		G	P	P	G	G	F‡	E		P	G	G	P	F	E	
17% Cr	G	G	G	P	P	G	E‡	P	E		G	G	G	F	F	E	E
17% Cr, 4% Mo																	
27% Cr	E	G	E	P	P	E	F	G	G		E	E	E	GE			
Silcrome, (8% Cr, 3% Si)	F			P	P	E	G	G	G						PG		
Stellite	E	E	E	F	G	E	G	E	E		E	E	E	G	G	E	E
Cr-Ni steels: 8-20				P	G	F	G	G	G	G				P		G	
18-8, 4% Mo				P		G	G	G	G		E	E	E	GE		E	E
18-8	G	E	E	P	F	G	G	G	E	G	FG	E	E	GE	F	F	E
18-12				P	F	G	G	F	G					G		E	E
18-35	G			P	G	P	P	F	G	G				?			
25-12	G	E	E	P	P	G	G	F	G	G	E	E	E	GE	G	E	
26-24	G	E	E	P	F	G	G	G	G	G	E	E	E	E	G	E	
Commercially pure Ni	G	GE	GE	G	G	P	G	G	E	E			G	P	G		
Nickel alloys: Monel metal	G	FE	FG	FG	G	P	G	G	E	G	E		G	P	E	F	
Nichrome, 60-15	G			F	F	F	G	G	G					P			
Inconel, 14% Cr	E	E	E														
80% Ni, 20% Cr	G			F	G	P	G	G	E								
Hastelloy	E	G	G	G	FG	G	G	E	E	G	G	G	G	E	G	G	G
Commercially pure Cu	FG	P	F	F	FG	P	FG	FG	FG					G	FG		
Copper alloys: Red brass	FG	P	P	P	FG	P	FG	FG	P					G	FG		
Tobin bronze				P	F	P	F	F	F					G	F	FG	
Phosphor bronze	P	P	F	P	FG	P	FG	FG	FG					G	FG		
Silicon bronze	G	P		F	G	P	G	G	FG	P				G	FG		
Aluminum bronze	FG	P		P	FG	P	FG	FG	FG						FG	G	
Nickel silver	G	P		F	G	P	G	G	G						FG		
Admiralty metal	FG			P	FG	P	FG	FG	P						FG		
Commercially pure Al	G	G	G	P	P	P	F	P	P					P	F		
Commercially pure Sn		G	G	P	P	P								P			
Commercially pure Pb	P	P	P	F	G	P	P	G	P	P					F		

E = Excellent; almost unlimited service
G = Good; will give good service
F = Fair; only to be used in temporary construction
P = Poor
FG = F to G PE = P to E PG = P to G
† E at low and P at high concentration
‡ Below 50°C.

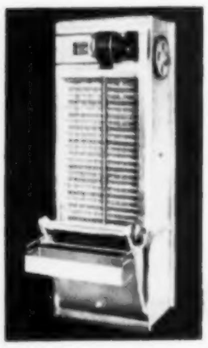
Compiled September 1933 by Jerome Strauss, Chief Research Engineer, Vanadium Corporation of America

Built o



The "George M. Pullman"—one of two all-aluminum Pullmans exhibited at A Century of Progress Exposition. Weight 96,980 lbs., including air-conditioning equipment. With ordinary materials it would weigh 180,000 lbs. Due to its light weight, it needs only 4-wheel trucks. (These are fabricated of Aluminum.) Yet it surpasses A. R. A. standards for strength and safety. Smart, modern decorative scheme in aluminum. Even the insulation is crumpled aluminum foil.

All industry finds the going easier with Alcoa Aluminum



MODERN VENTILATION USES THE MODERN METAL

Alcoa Aluminum makes this air-filter lighter, easier to install. This metal resists corrosion, isn't affected by moisture in the air, absorbs sound from vibration, not to mention its attractive appearance and long life.

SOMETHING NEW IN LIGHTING FIXTURES

Here Alcoa Aluminum helps with its light weight, its light-reflecting surface. A color-filter gives this fixture the appearance of expensive translucent glass but the light is really indirect. Made of deep-etched aluminum, it is equally attractive day and night.

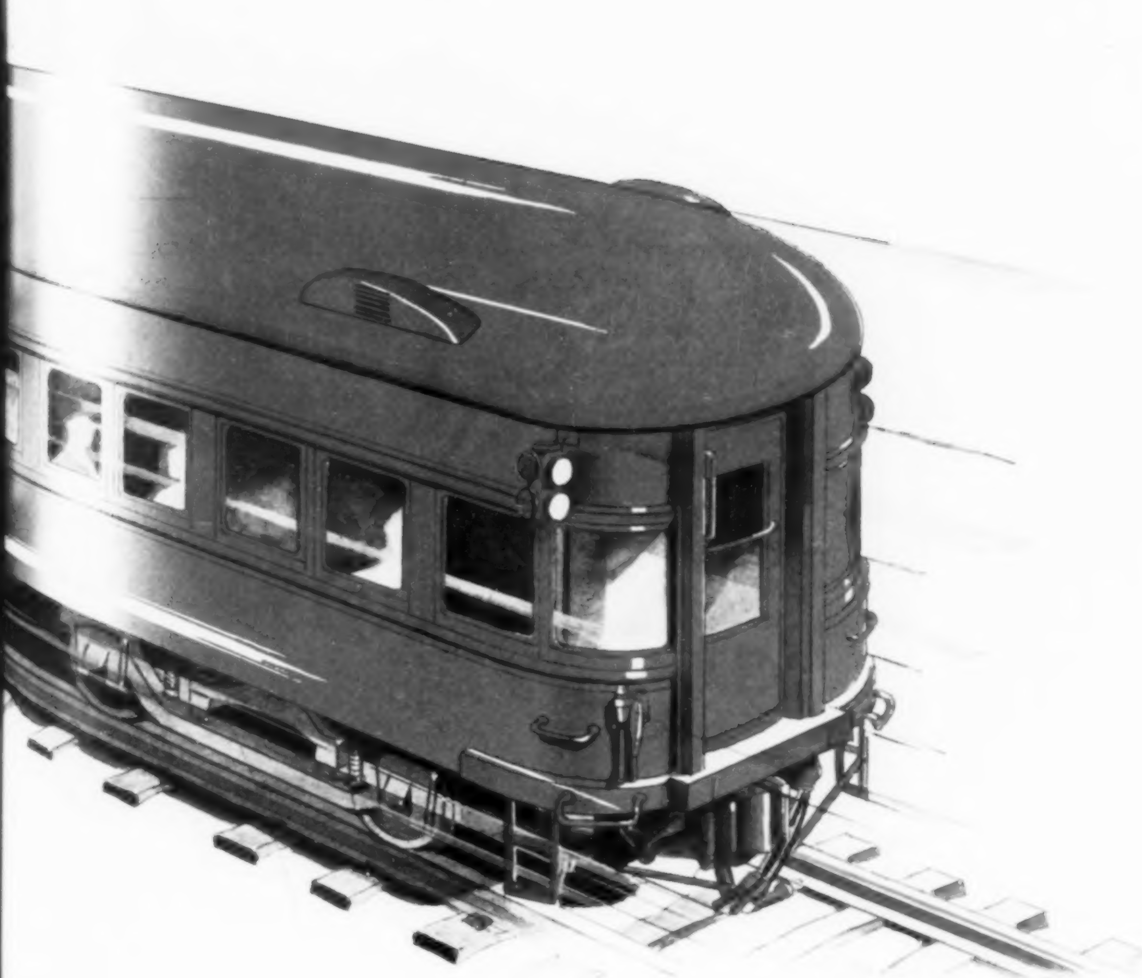
FOR EYE-HAZARDOUS JOBS

These goggles frames made of Alcoa Aluminum, are light in weight, easy to wear through the day's work—yet strong. *Alumilite* finish gives them attractiveness, longer life and corrosion resistance—an important detail in many plants.

Bringing efficiency and economy to industry, saleability to industry's products, Alcoa Aluminum is finding its way into most progressive plants. Light in weight, yet strong as structural steel, non-contaminating, non-magnetic, a good conductor of heat and electricity, this is the ideal metal for production equipment. To the finished product, Alcoa Aluminum brings ease of handling, durability, attractiveness. In the plant itself Alcoa Albron as a paint pigment protects against rust, weathering, smoke and acid fumes—makes brighter working conditions.

There's a place in *your plant* and *your* product for Alcoa Aluminum. Let us show you how to use, form and handle this metal. Please address: ALUMINUM COMPANY of AMERICA; 1801 Gulf Building, PITTSBURGH, PENNSYLVANIA.

ALCOA *Aluminum*



his New Pullman "Travels Light" and Safely

Builders of riding comfort and safety for three-quarters of a century, Pullman takes another step forward with the new "George M. Pullman"—made almost entirely of the light, strong alloys of Alcoa Aluminum. Cutting 50% from the weight of the standard Pullman, Alcoa Aluminum makes for swifter, smoother riding with even greater safety, greater durability of structural parts. Alcoa Aluminum comes in every form needed for car construction—extruded shapes and sections, rolled plates, structural shapes in any desired length up to 90 feet. For these reasons, too, *all* transportation units—buses, trucks, tank cars, mine cars, elevators—every form of mass in motion is rapidly being redesigned from the wheels up in Alcoa Aluminum.

ALCOA ALUMINUM

Letters From Abroad

Definition of Alloy Steels

SCHWEINFURT, GERMANY — Classification and standardization of plain and alloy steels is now a more pressing problem in German industry than ever before. The average purchase is small, delivery short, and unfamiliar vendors may have the only available stocks on hand. Hence the necessity for comprehensive specifications which will inform the vendor of the purchaser's requirements, enable the two parties to agree upon the price and commercial tolerances, and insure to the fabricator a uniform workability and response to heat treatment. In many respects the present German specifications fall short of this ideal.

Development of our industry led to a classification into (*a*) iron and (*b*) steel, and the term iron has been carried forward to represent iron-carbon alloys which were cast in the molten state from converters or open-hearth furnaces. At the present time the pronounced trend is to avoid the word iron, and to use the following general classification:

Class I — Plain steels; include soft and medium carbons; sold at base prices.

Class II — Alloy steels; corresponding roughly to S.A.E. steels, but including ingot iron and the strong structural steels; sold at a base price plus extras for alloy or processing.

Class III — Refined steels (*Edelstähle*, literally translated as "noble steel," or freely as "thorough-breds"); tool, die, and high alloys; sold at much higher prices.

In Class I the carbon content varies from about 0.05 to 0.60% depending upon the desired strength or elastic limit. Manganese is 0.80% max. and silicon 0.35% max. DIN standards stipulate three groups: (*a*) Forging steel for machine construction, (*b*) shapes and sections as rolled, (*c*) heat-treatable steels. Class I also includes the free cutting steels, which are not regarded as alloys despite their high sulphur and phosphorus.

Class II is difficult to subdivide, or even to define in a general way, for the analyses and properties have not been standardized (in accordance with the principle that standards should be written only for those steels which have long been proven to be acceptable to both sellers and buyers). In those standards previously published the attitude was taken that the requirements for each specific case would be sufficiently well understood to insure the shipment of suitable material. The naming or classification of these special purpose steels has therefore, been unduly neglected.

As a matter of fact Class II should not be defined simply as "alloy steels," but as special ingot irons or alloy structural steels. DIN standard 1662 is the general specification, although this is neither adequate nor inclusive. Maximum alloy content of steels furnished under this specification for use after heat treatment is as shown in the table under "Chromium-Nickel." If the steels are to be used in the as-rolled condition, the carbon is hardly ever over 0.17%, the manganese 0.50 and the chromium 1.1%. As much as 0.2% chromium is permitted in nickel steel without being regarded as an alloying element, on account of the difficulty of excluding it from the scrap or of slagging it completely.

Other groups of unstandardized steels in

Maximum Alloy Content of German Special Steels

Type	C	Mn	Si	Cr	Ni	Other
Chromium	1.00	0.60	0.35	1.60	–	–
Manganese	0.50	1.50	0.35	–	–	–
Nickel	0.40	0.60	0.30	–	5.00	–
Silicon	0.10	0.30	4.00	–	–	–
Vanadium	0.60	0.80	–	–	–	0.30 V
Molybdenum	0.60	0.70	0.40	1.20	4.50	0.40 Mo
Copper	0.20	0.65	0.35	–	–	1.00 Cu
Cr-Mn	0.90	1.00	0.45	1.00	–	–
Cr-Ni	0.40	0.80	0.35	1.30	4.50	–
Cr-V	0.50	0.80	0.35	1.20	–	0.20 V
Cr-Ni-Mo	0.30	0.60	0.35	1.30	4.50	0.50 Mo
Cr-Ni-W	0.30	0.60	0.35	1.30	4.50	1.00 W
Si-Mn	0.60	1.20	1.80	–	–	–

wide use falling into Class II are shown in the table. To it should be added (because of their properties rather than analysis) the unalloyed carbon-free ingot iron and the Izett steel. Higher prices for Class II are justified on account of the additional cost of the alloying metals, the extra time, labor and heat required to produce them, and the unusual cropping and surface chipping.

So much for the maximum alloy content of steels in Class II. As to the minimum which divides them from the plain carbon steels of Class I, a boundary must be set somewhere, since it would be difficult to agree as to the amount regarded as impurities or traces. Subject to the exception noted above for ingot iron and special carbon steels, the lower limit for alloy steel approximately marking German steelmaking practice is as follows: 0.1% for copper, molybdenum, tungsten, aluminum, vanadium or titanium; 0.2% for chromium or nickel; 0.5% for silicon, and 0.8% for manganese.

Class III, the refined steels (*Edelstähle*), may be subdivided into three groups according to microstructure — martensitic, austenitic and ledeburitic (eutectic shows in the ingot). Although none of this is official, the maximum alloy content of German commercial steels of this class varies according to use:

Martensitic steels: (*a*) For strength and toughness: 1.0% carbon, 0.5 to 1.5% of chromium, manganese, nickel and/or tungsten. (*b*) For high magnetic properties: 1.0% carbon, 0.5% tungsten, 2% chromium and/or cobalt. (*c*) For corrosion resistance: Up to 1.0% carbon, 15% chromium and about 1.5% nickel, manganese and/or cobalt.

Austenitic steels: (*a*) For strength and impact resistance: Up to 1.2% carbon and 12 to 14% manganese. (*b*) For heat resistance and non-magnetism: 0.5% carbon and 25% nickel. (*c*) For corrosion resistance and non-magnetism: 0.10% carbon, 20% chromium, 10% nickel.

Ledeburitic steels: (*a*) For strength: 2.8% carbon, 2% chromium. (*b*) For dies and shears: 2.5% carbon, 12% chromium. (If highest hardness is required the analysis would run up to 1.5% carbon, 6% tungsten, 1% chromium, 0.4% vanadium). (*c*) High speed steel, up to 0.9% carbon, 25% tungsten, 5% chromium, 18% cobalt, 0.5% vanadium, 2.0% molybdenum.

Common usage puts the pure carbon tool steels, carbon higher than 0.7%, in Class III with the refined steels, regardless of manganese and silicon content, because of the select raw material and careful manufacturing practices which are absolutely necessary.

HANS DIERGARTEN

Measurement of Weldability

PARIS, FRANCE — In the study and appraisal of welds, two distinct problems are met. First is the determination of the general value of a welded structure, which leads to the testing of pieces of fairly large and even great dimensions. Such tests are industrial rather than laboratory tests and may even extend to the study of completed bridges or tankers.

Second is an estimation of the aptness of metals to be put together by welding. This is a complex property to which the name "weldability" is given. Such a property may be evaluated only after laboratory studies have separated and determined its elementary factors.

The present writer recently endeavored to introduce some precision in the experimental determination of a numerical coefficient of weldability. This can be established by following some ideas summed up as follows:

In the first place it is necessary to evaluate the solidity and continuity of a typical welded joint in the given metal and application. Presence or absence of physical defects is determined by X-rays, magnetic surveys, density, and examination of the fracture, and by mechanical tests such as tensile, impact, and bending. The result is expressed by a "com-

Correspondence

pactness coefficient" C, varying from 1 to zero.

Next it is necessary to appraise the homogeneity of the welded joint, or to compare the properties at the joint with those of the original metal some distance back. The various properties taken for this evaluation depend upon the application; thus — tensile, compressive, and shear tests for static structures; impact for dynamic parts; corrosion resistance for chemical equipment. For every such property P_m of the original metal, a determination is made on a small sample of the weld metal and its minimum value P_w found. These various properties may be weighted by various numerical coefficients K representing their relative importance, each to each, and the "index of homogeneity" H is then computed by the formula

$$H = \frac{10}{\Sigma K} \Sigma \left(K \frac{P_w}{P_m} \right)$$

Suppose, for instance, that a sample of original metal in boiling nitric acid lost 0.002 grams per sq.cm. per day, whereas the weld metal lost 0.003 grams. Suppose further that the tensile strength of the original metal was 82,000 lb. per sq.in. and of the weld metal 75,000. Assume that some chemical equipment is to be built, wherein corrosion resistance is three times as important as strength. The index of homogeneity then becomes

$$H = \frac{10}{4} (3 \frac{0.002}{0.003} + \frac{75{,}000}{82{,}000}) = 7.3$$

Weldability, finally, will be evaluated by the coefficient

$$W = C \times H$$

the numerical value of which will fall between zero and 10. Obviously, two or more metals, tested and evaluated in this way, may be ranged in order of their usefulness.

This coefficient of weldability W depends not only upon the metal, but also upon the following factors: Initial state of the metal, subsequent mechanical and thermal treatments of the weld, welding process (oxy-acetylene, arc, or atomic hydrogen), nature of deposit, use of flux or gaseous atmosphere, use to which the welded pieces are to be put, dimensions and more particularly thickness of the joint.

Estimation of the mechanical homogeneity H, which is of capital importance, requires the use of very small test pieces to determine the properties of a very restricted region.

For this purpose, the present writer is proceeding to construct, jointly with M. Chevenard, some apparatus for making tensile, transverse and torsion tests on pieces a few square millimeters in cross-section. Such micro-apparatus for mechanical testing, in conjunction with the very small ball hardness tester or the diamond indenter, will parallel in physical laboratories the micrographical tests made so commonly in metallurgical laboratories. It will allow us to determine the mechanical properties of the samples studied microscopically or dilatometrically. This is essential to correlate the results obtained by the various investigative methods now in use.

ALBERT PORTEVIN

Ferromanganese for Export

GROSNY, U.S.S.R. — It is well known that two of the world's largest and richest deposits of manganese ore are located in the U.S.S.R. One of them at Nikopol in the Ukraine has been worked for a long time, and has always supplied the needs of our own steel industry, together with a considerable amount for export.

The larger and richer deposit at Chiaturi in the southern part of the Caucasus is of more recent development, but of more importance to our export trade. Its proven resources are estimated at 65,000,000 tons. Exports in both 1929 and in 1930 were about 710,000 tons of washed ore containing from 50 to 53% of manganese. While this represents the peak of production it also is an indication of the capabilities of the region from a trading standpoint. This tonnage somewhat exceeds that exported by British India, the most important source prior to the War, and greatly exceeds that of the recently developed West African deposits. From 40 to 50% of the manganese used in the United States comes from the Chiaturi ore body.

All this time there has been no ferromanganese smelted in the Caucasus, due principally to a lack of electric power. This has been removed by the construction of a 30,000-hp. hydro-electric

"WHERE TO, PLEASE?"

SCARCELY a day passes—sometimes scarcely an hour in the day—that you do not go visiting by telephone. It is truly the magic carpet that transports you, quickly and easily, to places you would like to be and people you would like to see.

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AMERICAN TELEPHONE AND TELEGRAPH COMPANY

Correspondence

station near the town of Mzchel. Construction of the first units of a 60,000-hp. power house on the Ryon river started summer before last, and the Economic Plan calls for a 150,000-hp. plant in Toporavany. It is intended to use much of this cheap power in electro-metallurgical industries to be developed simultaneously.

A project for the production of 78 to 82% ferromanganese in electric furnaces was approved in 1929 by the Georgian Economic Council and a committee of experts in Moscow. Designs were made by the German firm of Siemens & Halske. The first third of this plant has now been built (near the town of Sestaphony) and placed in operation about a year ago. Its present capacity is about 50,000 tons of ferro per year from three 7500-kva. Heroult-Helfenstein furnaces. Transformers supply three-phase current at 110 volts. Electrodes are 48 in. diameter of the self-baking type.

The plant is completely mechanized. Above each furnace are four hoppers for manganese ore, iron ore, limestone, and coke. Its chief purpose, as before stated, is to produce 80% ferromanganese to be exported instead of ore.

B. M. Suslov

Aluminum for Struts and Wire

TURIN, Italy — A pair of interesting notes on the uses and properties of aluminum alloys have recently appeared in my country. The first has to do with a considerable variation in the compressive strength of samples having identical tensile strengths.

Tests were made by C. Guidi on fabricated struts of duralumin whose length was about ten times the greatest transverse dimension, and reported to *Alluminio*. The two materials investigated were "alclad" (17-ST covered with pure aluminum) made by Aluminium, Ltd., and "bondur," of the Dürener Metall-Werke (described by Dr. Diergarten in September, page 56). The investigation was instituted by the fact that the two alloys — though showing the same tensile strength, elastic limit and elongation when tested under tension — had given very different results when used for compression members in the construction of hydroplanes.

While it would be tedious to give all the results obtained by Guidi, a few figures in the adjoining table will be sufficient to give a general view of the differences found when testing fabricated struts. Cross-sectional area ranged between 0.10 to 0.95 sq.in. For well-known reasons, struts made with thinner sections showed lower unit compressive strengths. It thus appears that the difference ranges from 12 to 15% in those thicknesses and sections generally used in aircraft.

Thickness of Flanges Inches	Unit Compressive Strength of Struts, Pounds per Square Inch — Bondur			Alclad			Difference Between Averages
	Max.	Min.	Average	Max.	Min.	Average	
0.020	15,800	15,000	15,300	13,800	12,800	13,500	13.5%
0.031	24,600	22,800	23,800	21,000	18,500	19,500	22.2%
0.039	28,600	27,400	28,300	24,900	24,200	24,500	15.4%
0.059	39,300	32,600	36,800	33,300	33,000	33,200	11.0%

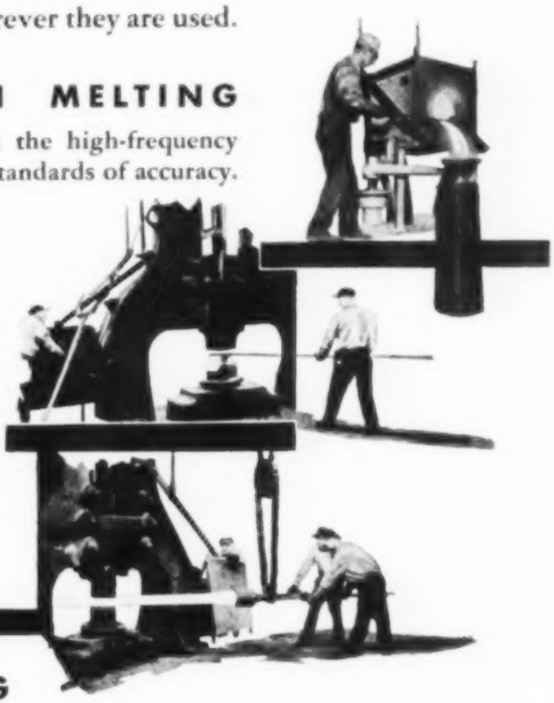
The other note I have to transmit concerns the installation of aluminum cable for high tension electric lines.

Regular operation of the large Italian plants for the production of aluminum only began in 1928, after many of the most important electric transmission lines had been built and equipped with copper cables. Since that time aluminum has been favored in Italy for this purpose, but in recent years the construction of new lines has been hampered from well-known economic reasons. This explains why Italy, having a late start in the production of her own metal, has comparatively few lines equipped with aluminum or aluminum alloy cables.

Nevertheless, of the 1260 miles of lines constructed during 1929, 1930 and 1931, 993 or 49% have been equipped with the light metal. It is also remarkable that the development of its use has not been greatly affected by the long depression in the copper prices, which fact confirms the importance of the technical advantages of aluminum alloy cables. *(Continued on p. 50)*

These 5 **steps** lead to superfine **TOOL STEELS**

QUALITY Tool Steels never "happen." The superfine quality of Bethlehem Tool Steels is built up, step by step, with infinite care and patience, throughout manufacture. Each process followed is representative of the most advanced steel-making practice. The result is inevitable: Tool Steels so uniformly fine as to bring marked economies wherever they are used.



HIGH-FREQUENCY INDUCTION MELTING

Bethlehem Tool Steels get the right start by melting in the high-frequency electric induction furnace, which makes steel to laboratory standards of accuracy.

LIBERAL INGOT DISCARD

Large discards, from both the top and bottom of the ingot, mean that the buyer gets only the "cream" of the tool steel.

HAMMER-COGGING OF INGOTS

It's far costlier to hammer-cog ingots than to roll them. But the tremendous impact developed under the 14,000-lb. hammer insures a complete working of the entire ingot and the breaking up of all undesirable ingot structure.

PROGRAM-CONTROLLED ANNEALING

The exact heating, soaking and cooling curve desired is obtained by a motor-driven cylinder on which the edge of a plate guides the temperature regulator. Possibilities of human error are eliminated.

RIGOROUS INSPECTION

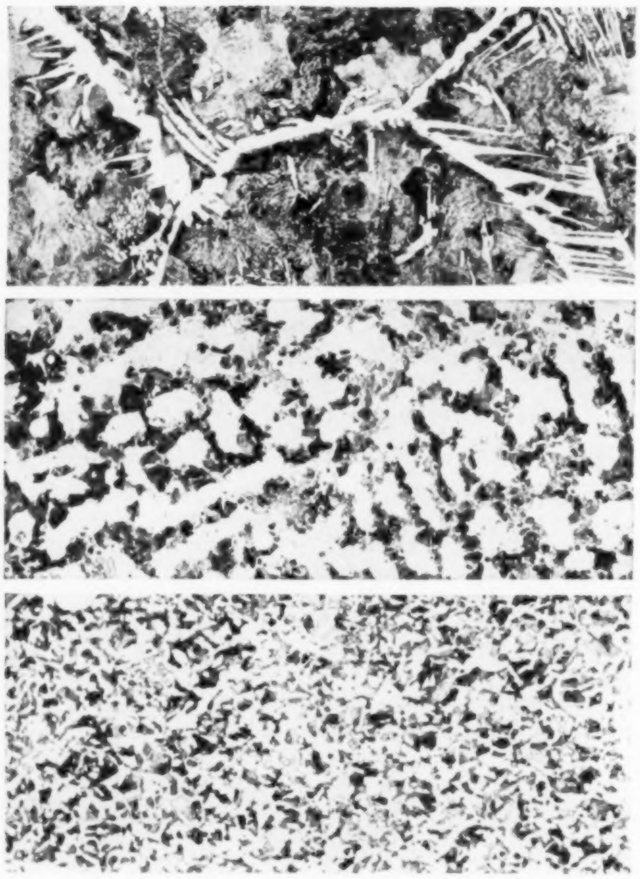
Thoroughly representative cross-sections for inspection are obtained by cutting slabs from the tool-steel billet stock before rolling, and cutting discs from the finished bars.

These samples are subjected to hot-acid etch, hardenability tests and microscopic examination.

BETHLEHEM STEEL COMPANY

GENERAL OFFICES: BETHLEHEM, PA.

BETHLEHEM TOOL STEELS



Top: Structure of cast steel (no heat or mechanical treatment.)
Center: Same steel, annealed. Lower: Same steel, forged.

What about the
Grain Size?

WHEN the structure is correct but the machinability or tensile strength does not meet the requirements look to the grain size for the solution.

Deformity of grains by cold working and abnormal growth under certain annealing conditions often cause trouble in such operations as drawing, etc.

Bausch & Lomb Metallographic equipment equipped with a micrometer eyepiece will assist you in locating the trouble. We can help you if you will write to us about your problems.

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Correspondence

A survey made as of 1931 of five important European countries shows that in the very high voltage lines (200,000 to 250,000 volts) aluminum is used exclusively, except in Germany.

In England all lines of 85,000 to 200,000 volts are also of aluminum, aluminum alloy, or steel-cored aluminum. In France, Switzerland, and Germany the proportion is 730 miles to 445 miles for copper. For voltages below 50,000 copper has the great predominance in all Europe.

FEDERICO GIOLITTI

Strength of Bolts

NEUSS, GERMANY — We have read with great interest E. M. Slaughter's article "Tests on Threaded Sections" in the March issue. At the leading German nut and bolt factory, Bauer & Schaurte, A.G., a very simple method of calculation has been developed to get the true tensile strength of a threaded section. The result of a long series of tests, published by the undersigned in *Maschinenbau* in 1932, showed that correct values are obtained if one uses 112% of the root area when calculating the strength of a bolt.

It is apparent from inspection of the table below that the areas obtained by our method and Mr. Slaughter's method check very closely:

Size of Bolt In.	Root Area plus 12% Sq. Mm.	Area on Mean Diameter Sq. Mm.	Difference
1/4	19.620	20.636	−4.8%
5/16	33.048	33.039	+0.03
3/8	49.349	50.182	−1.6
7/16	67.916	68.632	−1.3
1/2	87.744	86.739	+1.01
5/8	146.717	146.237	+1.0
3/4	219.428	216.325	+1.01
7/8	303.956	298.575	+1.02
1	400.196	391.678	+1.02

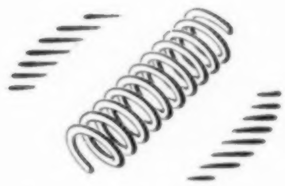
The per cent difference was calculated with the values for mean diameter (National Acme Co. basis) as 100. It is seen to be inconsiderable. Consequently our method gives values for tensile strength closely comparable to the one commended by Mr. Slaughter, and later, we understand, adopted as a tentative recommended practice by your Society.

KARL SCHIMZ

...and now

BERYLLIUM-COPPER

sheets – wire – rods – tubes – forgings



A heat treated Beryllium-Copper coil spring withstood 10,000,000 cycles of deflection without indication of failure—an illustration of the remarkable fatigue limit values obtainable in this alloy.

BERYLLIUM-COPPER is a relatively new alloy being produced commercially by The American Brass Company.

The most notable characteristic of the alloy is the remarkable improvement in physical properties which can be brought about by heat treatment. In the annealed condition, Anaconda Beryllium-Copper wire, for instance, has a tensile strength of about 74,000 p.s.i. and by a correctly selected heat treatment, this tensile strength may be increased to any desired value up to 181,000 p.s.i. Similar increases are achieved in hardness and fatigue limit.

Whether annealed or cold worked, Anaconda Beryllium-Copper can be fabricated by usual methods, after which finished parts may be physically improved by heat treatment.

A copy of Anaconda publication B-21 describing this alloy in more detail and giving general heat treating instructions will be sent upon request.

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General Offices: Waterbury, Connecticut
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metals

Tungsten Powder ... *97–98%*
Pure Manganese ... *97–99%*
Ferro-Chromium ... *60%*
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Required by the act of Congress of August 24, 1912, of METAL PROGRESS, published monthly at Cleveland, Ohio, for October 1, 1933, State of Ohio, county of Cuyahoga, ss.

Before me, a notary public, in and for the State and county aforesaid, personally appeared Ray T. Bayless, who, having been duly sworn according to law, deposes and says that he is the assistant secretary of the American Society for Steel Treating, and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management, etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, postal laws and regulations, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, American Society for Steel Treating, 7016 Euclid Avenue, Cleveland, Ohio; Editor and Managing Editor, Ernest E. Thum, 7016 Euclid Avenue, Cleveland, Ohio; Business Manager, W. H. Eisenman, 7016 Euclid Avenue, Cleveland, Ohio.

2. That the owner is: The American Society for Steel Treating, 7016 Euclid Avenue, Cleveland, Ohio, which is an educational institution, the officers being: President, W. B. Coleman; Vice-President, W. H. Phillips; Treasurer, A. T. Clarage; Secretary, W. H. Eisenman; Directors, C. F. Pascoe, R. S. Archer, H. G. Keshian, H. D. McKinney and A. H. d'Arcambal. All above officers of the American Society for Steel Treating, address at 7016 Euclid Avenue Cleveland, Ohio.

3. That the known bondholders, mortgagees and other security holders are: none.

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RAY T. BAYLESS, *Assistant Secretary of the American Society for Steel Treating.*

Sworn to and subscribed before me this 27th day of September, 1933.

ARTHUR T. WEHRLE (Seal)
Notary Public. (My commission expires January, 1935)

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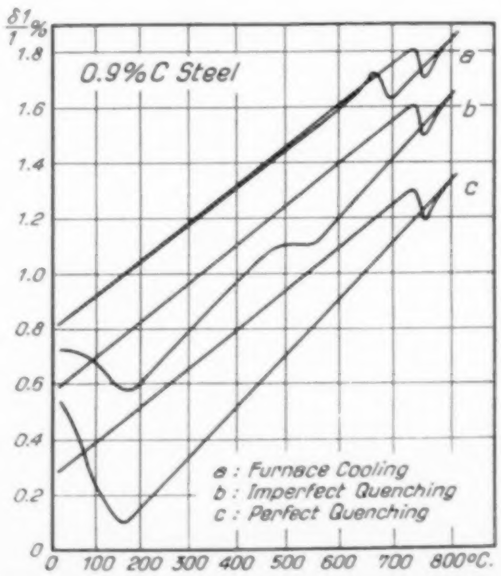

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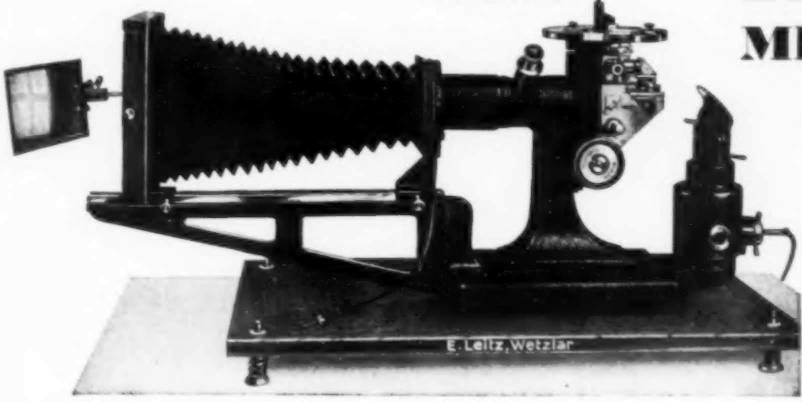

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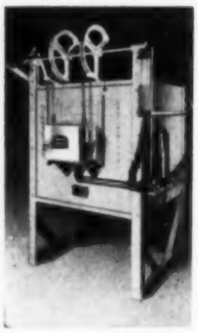

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Spoilage is eliminated when high speed steel is hardened in Certain Curtain electric furnaces, claims a new booklet issued by C. I. Hayes, Inc. Grain growth is controlled and the most delicate tools develop maximum hardness without decarburization, scaling or fusing. Bulletin No-15.

Optics in Metallurgy

A surprisingly large number of uses for optical instruments in metal working are described in a new booklet of Bausch & Lomb Optical Co. Photomicrography is, of course, prominent among these, but this well illustrated booklet shows many other interesting optical instruments. Bulletin No-35.

New Hardening Method

All three vital factors in correct hardening are completely controlled by the new Vapocarb Hump method of hardening, which is well described in a Leeds & Northrup bulletin. The three factors are: Quench point, rate of heating, and furnace atmosphere. Complete details are given in Bulletin No-46.

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A new Enduro has just been developed by Republic Steel Corp. — Enduro 4-6% Chromium, which is a fine heat resisting alloy. A new handbook gives full information which will be appreciated by designing and research engineers, metallurgists and metal plant executives. Bulletin No-8.

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Beryllium-Copper is a relatively new alloy produced by American Brass Co. which can be heat treated to tensiles as high as 181,000 lb. per sq.in. It is supplied in sheets, wire, rods, tubes and forgings. An excellent booklet gives full information on fabrication and treating. Bulletin No-89.

Bright Annealing

A publication of Electric Furnace Co. describes new developments in controlled atmosphere furnaces for continuous deoxidize annealing, bright normalizing and bright annealing both ferrous and non-ferrous metals. Sheets, strip, coils, tubing and wire come clean, bright and dry from these furnaces. Bulletin No-30.

Water Treating

Dearborn Chemical Co. has prepared a booklet describing the operation of their lines of water treating units and testing equipment. Photographs and drawings illustrate the equipment and the text describes the manner of operation. Bulletin No-37.

Nitriding Facts

Information on possible new applications of Nitralloy and the nitriding process in view of recent developments may be obtained from Ludlum Steel Co. New economies in production and a better product may now be obtained. Bulletin Jn-94.

Roll Grinding

Carborundum Co. has just published a 50-page booklet on roll grinding which may be considered a handbook of available information on this subject. Carefully written and amply illustrated, this treatise will undoubtedly be of real practical value. Bulletin Au-57.

High Cr Cast Iron

A pamphlet describing foundry production of cast irons containing from 15 to 30% of chromium has been issued by Electro Metallurgical Co. These cast irons do not grow or scale after repeated heatings and are excellent for high temperature work. Bulletin Ma-16.

"Vee-less" Arc Welds

New literature covering a very recent development in arc welding has been prepared by Metal & Thermit Corp. Known as Murex Straight Gap welding, the new process eliminates grooving or "veeing" the edges even of heavy plates. Welding time is halved and other savings are effected, it is claimed. Bulletin My-64.

Stainless Sheets

A very useful booklet describing the stainless steel sheets and light plates made by American Sheet & Tin Plate Co. gives recommendations for fabrication and a description of finishes and analyses available. Bulletin Ap-96.

X-Rays in Industry

General Electric X-Ray Corp. has available a profusely illustrated brochure entitled "Industrial Application of the X-Ray," which gives the complete story of the field of application of this modern inspection tool. Valuable information is presented. Bulletin Ma-6.

Sheffield Steel

Wm. Jessop & Sons, Inc., in a recent publication explain why their Sheffield Superior oil hardening steel does not distort and is easily machined. They assign as reasons a special anneal and a proper balancing of the carbon, manganese and tungsten contents. Full details are presented in Bulletin Jn-61.

Continuous Carburizing

Furnaces for continuous gas carburizing by the Eutectrol process are described in a new folder by Surface Combustion Corp. Photographs of installations and performance data are used to show the advantages of the process. Bulletin Oc-51.

Choosing Nickel Steel

International Nickel Co. has an ingenious chart to show at a glance the nickel alloy steel compositions and treatments needed to develop yield points in section sizes from 1 to 12 in. It is useful in selecting bars, shafting and forgings of simple shape. Bulletin Au-45.

Globar Elements

Globar electrical heating units and a variety of accessories for their operation have been catalogued by Globar Corp. A list of the standard industrial type heating elements and a coordinated list of terminal mountings and accessories is included. Bulletin N-25.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in one of that company's publications. Bulletin D-17.

X-Rayed Alloy Castings

A folder just issued by Electro Alloys Co. describes their X-Ray inspection service of Thermalloy heat resisting castings for high temperature work. Considerable data on the use of X-Ray tubes and "radon" capsules to check foundry practice are presented. Typical radiographs and tables of physical properties are included. Bulletin Oc-32.

Titanium Cast Iron

The effects of titanium on the structure and properties of gray cast iron, especially as contrasted with those of other commonly used alloys, are described in a pamphlet offered by Titanium Alloy Mfg. Co. The results given were obtained by regular operating practice in several foundries and not solely by laboratory experiments. Bulletin Jl-90.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is the usual practice. Bulletin Fe-13.

New Zinc Coating

Wire which has been zinc coated by the new Bethanizing process is described in Bethlehem Steel Co.'s latest folder. This process produces a zinc coating which has proved to be more ductile, tighter, tougher, more uniform and purer. Coatings 3 times as heavy as formerly can be made. Bulletin Au-76.

Uses of Molybdenum

Climax Molybdenum Co. offers a new and useful 50-page booklet dealing with the benefits conferred by molybdenum as an alloying element in iron and steel. In orderly fashion engineering data are presented and made clear with numerous tables and illustrations. Bulletin Au-4.

Maintenance Welding

This interesting booklet describes the use of the oxyacetylene process in the reclamation of broken and worn machine parts, alteration, fabrication and installation of equipment. Such equipment as piping, tanks, machine elements, engine and pump parts and conveying systems is covered in the 16-page illustrated booklet of Linde Air Products Co. Bulletin Jl-63.

Electric Furnaces

Full details of the line of electric furnaces made by Hoskins Mfg. Co. are well presented in their latest 42-page catalog. Contents include description and data on 17 types of furnaces and some valuable information on Chromel resistance wires and thermocouples. Bulletin Sp-24.

How to Work Stainless

A very handy booklet on stainless steel is offered by Carpenter Steel Co. It has been compiled for quick reference and contains accurate working data on all forms and types of stainless which should be extremely helpful in working out manufacturing problems. Bulletin Oc-12.

Cyanide Baths

Much practical information on the heat treatment of steels with cyanides and salts is contained in a descriptive booklet of E. I. duPont de Nemours & Co., R. & H. Chemicals Dept. The booklet contains many valuable suggestions for improved quality heat treating. Bulletin Sp-29.

New Furnace Blowers

Two new types of Turbo-Compressors are described in recent publications of Spencer Turbine Co. Uses for the ⅓ hp. Turbo are presented, as is a description of the new single stage Turbo-Compressor which affords tremendous economies in low pressure gas and oil fired equipment. Bulletin Sp-70.

Quenching Handbook

E. F. Houghton & Co. have published an excellent 80-page handbook on the subject of quenching. More than 30 charts and photomicrographs help tell the story. A copy will be sent free to those who request it. Bulletin Jl-38.

Quicker Heat Treating

Driver-Harris Co. discusses Nichrome sheet containers for heat treating in an illustrated folder which honestly states that while for certain purposes sheet containers cannot be used economically, there are a multitude of installations where their advantages of lightness and quicker heating can be fully utilized. Bulletin Jl-19.

Darkfield Microscopy

Comparison is made of darkfield and brightfield metallographic examination in a 16-page publication of E. Leitz, Inc. The equipment necessary for darkfield microscopy is described and prices are given. Several sets of micros of the same field contrast the two methods of illumination. Bulletin Ja-47.

Pickling Inhibitors

A pamphlet describing the nature and use of Grasselli Inhibitors is available to all those interested in the pickling of steel. It not only describes the merits of these inhibitors, but it gives a table of suggested inhibitor strengths to be used in the pickling of the various grades of steel. Bulletin Ap-95.

Electric Pot Furnace

American Electric Furnace Co. has just published a new 4-page folder showing the construction features and giving the operating advantages of their "American" electric pot furnace as used for lead, salt and cyanide baths. Bulletin Oc-2.

Aluminum vs. Corrosion

In the carefully prepared booklet, "Combating Chemical Corrosion with Alcoa Aluminum," published by Aluminum Co. of America, effects of various corrosive agents upon aluminum and its alloys are described in detail. It is an excellent and convenient source of information on this subject. Bulletin Sp-54.

New Foxboro Pyrometer

Foxboro Co. describes the new Foxboro potentiometer recording pyrometer in a recent bulletin. The outstanding features are a new design of balancing mechanism, ability to make from one to six records, a 12-in. chart, rapid recording cycle and a moisture-proof case. Bulletin Au-21.

New Heat Controller

"Straight Line Control" of furnace temperature is possible with the Trendalizer Controller made by Brown Instrument Co. There is no zig-zagging across the control point, because this unique device changes its control action in accordance with both temperature trend and extent of deviation. Bulletin Sp-3.

To Prevent Rust

The well known rust preventive, No-Ox-Id, is now available from Dearborn Chemical Co. as a foundation for paint. It is available in the colors red, gray or black. A booklet explains how maximum resistance to corrosion can be obtained. Bulletin Ju-36.

Hardness Testing

Everyone interested in the testing of metals for hardness will do well to have on hand a copy of a catalog recently issued by Wilson Mechanical Instrument Co., illustrating and describing the latest design of Rockwell Hardness Testers and auxiliary work supports. Bulletin Sp-22.

Scleroscopes

The model D standard recording scleroscope is described and illustrated in a recent publication of Shore Instrument Co. The theory and practice of hardness testing with this portable machine as described in this bulletin reveal a fund of valuable facts. Bulletin S-33.

New Type Furnace

A new bell-type retort furnace made by American Gas Furnace Co. can be used in quick succession for carburizing, nitriding, bright annealing in gas atmospheres, or for hardening, normalizing, tempering or annealing. It is an ideal heat treating tool where production is widely varied in character. Bulletin Jn-11.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. The information given is complete and authoritative. Bulletin S-27.

Metal Progress
7016 Euclid Ave., Cleveland.

Please have sent to me without charge the following literature as described in the November issue. (Please order by number only.)

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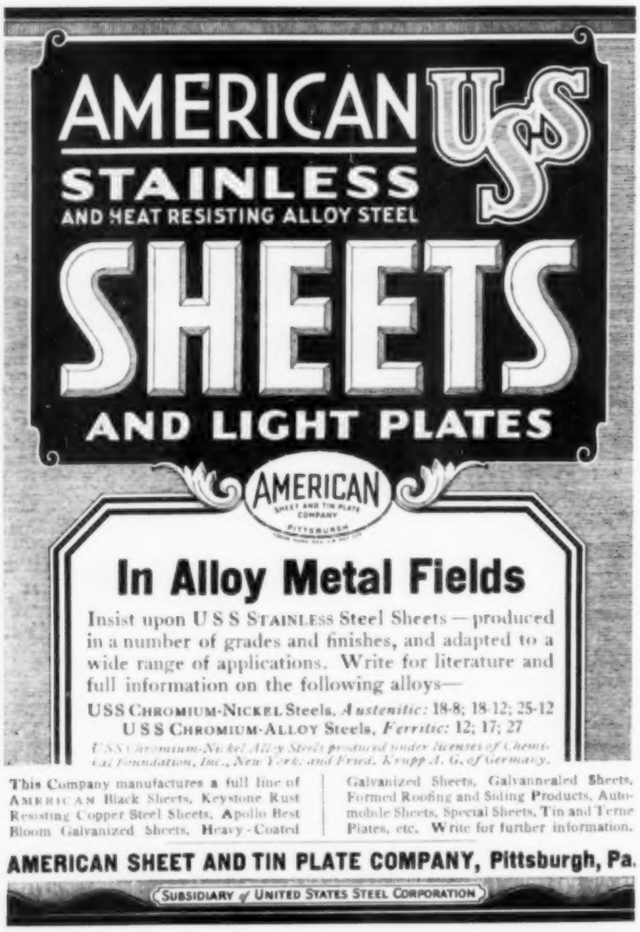

Flakes

(Continued from page 17) a very sordid appearance, while the other actually had pieces as large in diameter as a nickel pull out during the rough machining operation, presenting a bright, coarse crystalline fracture. Subsequent investigation showed this material to be full of the typical flakes, and the unaffected surrounding material presented the well-refined heat treated structure.

On checking back we found that the ingot from which these two forgings were made had been stripped immediately after solidification, transferred at once to the forge furnace, and the forged slabs laid on the floor to cool. The ingot itself had not cooled through its normal critical stages, and the forging heat had had little effect on the primary ingot structure — what breaking down had been effected was the result of mechanical work. When these forgings were laid out to cool, they were in part actually cooling down from the casting temperature and not from the forging heat. Therefore, it is easy to realize why these forgings still had a very coarse structure and were in such condition as to permit the spread of internal ruptures when passing through the critical range.

Recently there has been a growing demand for alloy steel castings — particularly for those containing approximately 5% chromium, where both strength and corrosion resisting properties are required. The unsuspecting steel founder, not fully conversant with its volume change at a low temperature critical range, is learning (by the costly experience of many castings rejected for small internal cracks) the necessity for more careful control. This material, immediately it is released from the mold and while still showing a red color, must either be charged at once into a furnace already at a red heat and allowed to cool slowly in the furnace, or else covered with loose clinker to allow freedom of movement as the casting cools and then buried in dry floor sand to exclude air and prevent chilling. After having cooled to approximately 300° C. by either method, the castings should then receive their correct treatment to refine the structure.